HIGHWAY TRESTLES, BRIDGES AND CULVERTS

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Highway Trestles, Bridges and Culverts

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A Simple and Economical Type of Highway Bridge

Contents

Foreword

THIS Bulletin has been made possible through the kind co-operation of state highway engineers and others in furnishing references, plans and details which served as a basis for the drawings shown. Credit has been given on the drawings in each case. Valuable references from Professor Henry S. Jacoby, Cornell University, and the use of sections from the standards of the various engineering associations, together with quotations from engineering texts are hereby acknowledged.

Highway Trestles, Bridges and Culverts

By C. E. PAUL, Construction Engineer

CHAPTER I.

THE USE OF WOOD IN BRIDGE CONSTRUCTION.

Wood has been one of the standard materials used in bridge construction for centuries. The earlier types of structures were designed and built by men who had but little if any training in engineering theory, and who based their efforts on precedent and good sense. These bridges were of substantial construction and gave excellent service. In fact many of them may be found today in different parts of the United States which have been in use for nearly a century and still give satisfactory service. The old time bridge builder or carpenter paved the way for the present engineer with his knowledge of principles and methods. Precedent has been amended by the theory of stresses and the effects of loading, until the bridge of today is a nicely balanced engineering structure.

The advent of the rolled steel structural shape and the more modern material, reinforced concrete, has not taken away the value of wood in bridge building nor lessened its efficiency as a structural material. The attention of designers has been attracted to these newer materials and larger fields of engineering design have been opened, but the demand for wooden bridges of moderate size in both the railway and highway types is maintained on account of the special advantages pertaining to wood alone.

Advantages of Wood The advantages of wood as a material for highway bridges are mainly its general availability; comparatively low cost; lack of contraction and expansion due to temperature; its combination of

lightness and toughness, strength and elasticity; ease of working and handling; and the fact that work may progress in cold weather.

Good lumber is just as obtainable, possesses the same structural characteristics, and is as safe and economical today as it ever was. In fact, with wider transportation facilities, better seasoning and closer classification of kinds and grades, timber is more generally available and the quality better adapted to varying requirements than twenty years ago. Supplementing these advantages are the recent data on physical characteristics, and the development of wood-preserving and fire-retarding materials and processes.

United States Government estimates conservatively place the amount of merchantable standing timber in the United States at over 2,800 billion feet. This fact will interest engineers who have been led to believe that the supply of timber is nearly exhausted. Forest Service experts have stated that for the next thirty or forty years at least, there is no question as to the ability of the United States to furnish high grade structural timbers from its forests, to meet almost any demand from any part of the world. It is also estimated that the present merchantable supply of timber will last nearly sixty years at the present rate of cutting, even with no protection to present standing timber and no re-planting.

Changes in Traffic

Bridges are designed to carry loads across a given span. This distance may be covered by a single span or by a number of connected units each having its individual supports, depending upon the amount of load to be carried and the distance between piers or supports. The load is determined by the kind of traffic which is likely to come on the structure, and from this combination of length and loading the sizes of the bridge members are calculated.

It is readily seen from this basis of design that wide changes in traffic conditions will seriously affect structures which have been designed for a given loading. Highway standards which were set twenty years or even ten years ago are now becoming obsolete. The old, slow-moving road roller or traction engine

loading may be replaced by the modern, heavier and faster moving motor truck. This means that the factor of safety in many highway bridges built under the old plan of loading has been decreased, and in some cases to so great an extent that they are being remodeled or replaced by new structures long before their normal period of usefulness has been reached regardless of the material used. Where such bridges have not been remodeled to meet new conditions, traffic has been limited to a moving load of a given amount and the public is warned of this limit by signs placed at each end of the bridge. In other words, the structure has out-lived it real value as a public convenience, but in many cases its first cost has been too great to consider replacement after so short a time, and the material or design used will not allow easy alterations.

Timber as a Bridge Material

No engineer can prophesy what amount or kind of loading the traffic of even five years hence will demand from highway bridges. Wooden bridges are especially adapted to meet this uncertainty through their low cost when compared with those of other materials, their reasonably long period of service when properly built and the ease with which they can be strengthened or altered to meet new conditions.

The chapters which follow describe general types of timber highway bridges which have been found to give good service, and illustrate details necessary for proper construction. Bridge engineers from different parts of the United States have submitted designs of successful structures which have become standards in a given locality. These serve as a basis for safe and economical design to meet similar conditions.

CHAPTER II.

LOCATION AND SUBSTRUCTURE.

The location of the ordinary highway bridge is determined by the line of the road of which it forms a part. Often this cannot be altered and the bridge engineer has to meet conditions as they exist, but if it is possible to choose a site for the structure, the permanency of the present channel should be of first importance. In flat country where the soil is light or sandy, streams with a winding course are likely to change their channel during extreme high water. The narrowness of the channel; presence of high banks; relation between the normal depth of water and maximum depth; absence of sharp bends, islands or other obstructions which would tend to change the normal direction of flow, should all be considered in locating the bridge. It is advisable to have the line of crossing at right angles to the center line of the channel if possible.

If masonry or concrete piers or abutments are to be used as a support for the bridge or in the approaches, the character of the soil should be examined to determine the amount of excavation necessary for footings. This will also show the amount of material needed in the substructure after the height of bridge floor above extreme high-water line and the force of the current have been estimated. The cost of protection work and its maintenance should also be taken into account.

Profile of Location

After the location has been chosen a profile of the stream or depression which the bridge is to cover should be made. The profile should show the exact contour of the banks and bed of stream. This map serves as a basis for locating the extreme high and low water levels, the bottom of foundations, level of top of bridge floor, and aids in determining the kind of approaches most suitable. It will also give information needed in locating supports or piers, and choosing length of span or spans.

Substructure The substructure of a bridge consists of all parts which form the support of the bridge proper such as abutments, piers, foundations, framed bents, or piling. The materials used for the substructure are masonry, concrete and timber.

The type of substructure needed depends upon the kind and size of bridge, its loading, location, character of bed of stream, swiftness of stream, and danger from ice or floating objects. Wood piles are used extensively in both large and small structures, and also as supports for concrete piers in cases where the expense of excavating to a firm footing would be excessive. Framed timber bents may take the place of piles when a mud sill or sill resting on masonry foundations forms a part of the structure. Masonry or concrete piers and foundations are used where the soil is firm and no great amount of excavation is necessary, where the supporting piers bear heavy loads, or where the stream conditions demand heavy construction.

Timber Substructure There are two general classes of substructure consisting of timber members. These consist of ordinary wood pile bents capped with a piece of heavy timber to form a support for the stringers, and framed structural timber bents with cap and sill.

The pile type of construction is generally used where the ground is soft or where water is present a part or all of the time, and is commonly limited to a height of 30 feet. Bents of either four or six piles, capped with a 12-inch square timber, are sufficient for a roadway from 16 feet to 20 feet wide.

Sway bracing is not needed for pile or framed bents under 10 feet in height if the piling is driven into the ground to a depth of 8 or 10 feet and has a good bearing, but for heights between 10 and 20 feet the bents are braced by a pair of diagonal sway braces about 2 by 12 inches in size placed in the form of a cross. These braces are on opposite sides of the piling and are fastened to the cap and posts by ¾-inch bolts with a washer under both the head and nut. Bents over 20 feet high require special bracing.

Framed bents consist of four posts 10 inches or 12 inches square supported upon a sill which may rest directly on the

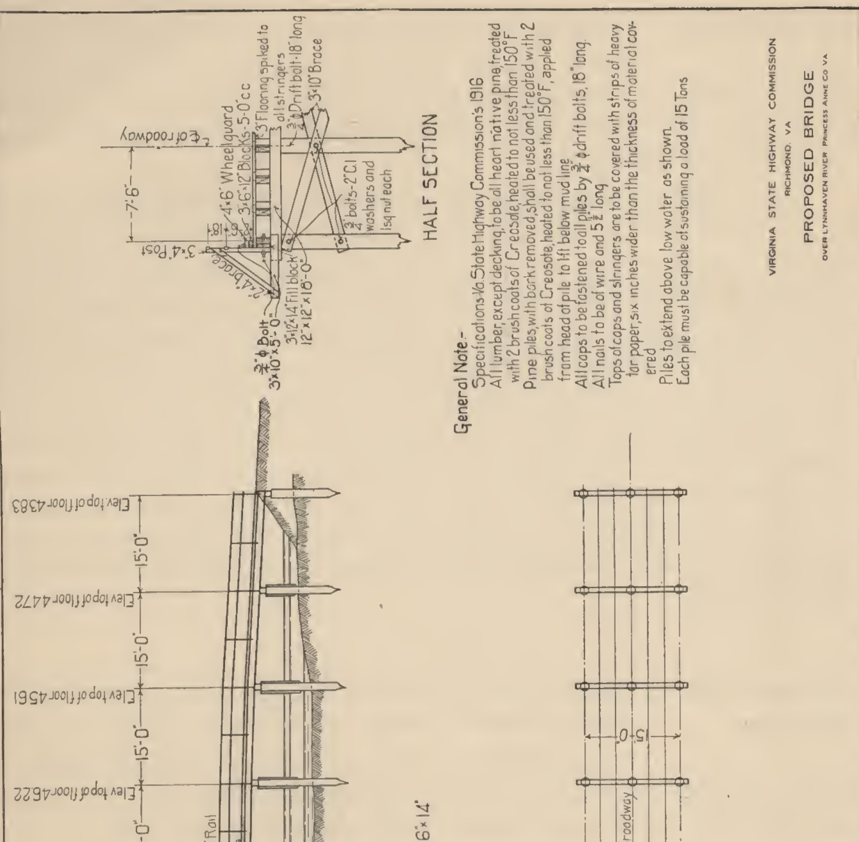


Fig. 1. Highway Bridge with Timber Substructure.

ground or upon a pile or masonry foundation and capped by a 12-inch square timber. Sills in contact with the earth should be thoroughly creosoted to prevent decay. They should be raised above the ground level if possible. Sizes of material for sills vary from planks 3 inches thick up to solid timbers 12 inches square, the larger timbers giving better service. The various members of a bent may be joined by drift bolts, mortise and tenon joints, dowels or plates. Joints will be discussed in a later section.

The spacing between bents of a pile or framed structure will vary according to the length and size of stringers which are to be used, but it generally lies between 12 and 22 feet, with about 15 feet as an average. The bents should be spaced equally along the structure if circumstances will allow.

Wood Piles Wood piles make a very satisfactory type of substructure when driven properly and used in suitable locations. It is not advisable to use untreated wood piling in salt water where it is liable to attack by marine borers, but if driven in fresh water or in the ground, it may be used with safety. Piling under water or in the mud will last for a long period of time. If alternately wet and dry, it is liable to decay and those parts should be given some form of preservative treatment to prevent this danger. For general work, a coal-tar creosote treatment has given the most effective results.

Timber for piles should be straight, sound, strong, free from defects, susceptible to preservative treatment, low in cost, and preferably stripped of bark, before driving. It is important that they be cut from sound, growing trees of a variety that will stand driving without splitting or undue brooming. The use of driving rings is specified in many cases.

For ordinary highway bridges the piles should have a diameter of at least 8 inches at the small end and 10 inches at the butt. They should be of sufficient length to develope the required bearing capacity in the soil in which they are to be used. If the tops extend above low-water elevation, it is preferable that the piles be given preservative treatment. If they are to be used with a concrete cap, the head of the pile should bed at least 12 inches in the concrete.

The spacing of piles should not be less than 2½ feet when used in groups, and the maximum load carried by any pile should not exceed 20 tons. They should be driven to a depth of at least 10 feet in hard soil and to at least 20 feet in soft soils if the pile is to be loaded to its full capacity. A common rule is to drive the pile until the penetration will not be more than 1 inch for each of the last six blows from a 2,000 pound hammer dropping freely through 20 feet.

The safe load on piles may be estimated by the Engineering News formula for a drop hammer:

$$P = \frac{2\,W\,H}{S + 1}$$

in which P is the safe load on the pile in tons; W is the weight of the hammer in tons; H is the free fall of the hammer in feet; and S is the average penetration of the pile for the last six blows from the hammer.

Abutments The abutments serve as supports at the end of the bridge and hold the fill in place at the approaches. They may consist of timber, wood piling, masonry, or concrete. Examples of log cribbing and timber abutments are shown in Figs. 2 and 3. Where such abutments are subjected to alternate wet and dry conditions, those parts of the wood which are affected should be given preservative treatment to prevent decay if long service is desired.

Concrete abutments may be either plain or reinforced. Plain concrete abutments should have a width of base equal to four-tenths of the height from the grade of the roadway to the bottom of the abutment. If the abutment rests directly on the soil, the base should extend at least 3 feet below the bottom of the stream unless solid rock or hardpan is reached at a less depth. A solid footing is necessary for such abutments, even if they have to be supported on wood piling driven into a soft bed. Plain concrete abutments up to 6 feet in height do not generally need reinforcement, since the width at the top necessary for the bridge seat will provide for sufficient width at the bottom. If reinforced concrete abutments are used the design should be based upon the earth and water pressure to be resisted.

The wings of abutments which hold back the fill and protect it from the action of the stream generally make an angle of 30 to 45 degrees with the face of the abutment, the object being

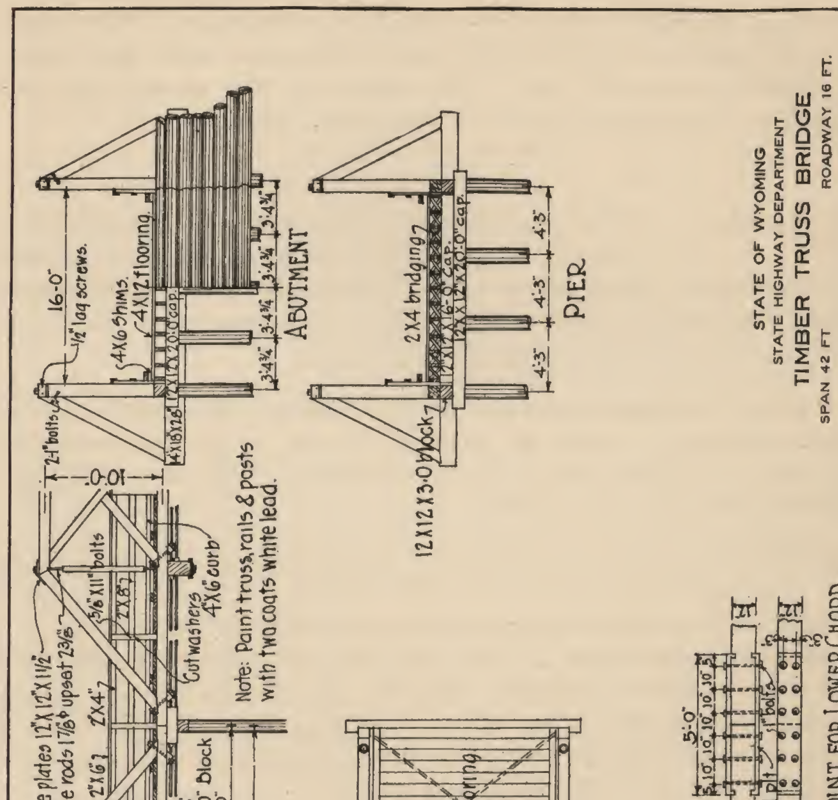


Fig. 2. Log Cribbing Abutments.

to keep the fill in place in a satisfactory manner. The wings on the upstream side should slant backwards more than those on the downstream side if the banks of the stream are low and the approaches require considerable fill.

Approaches The approaches leading to the main structure generally consist of earth embankments with sloping sides, or timber trestles. In either case the approach should lead gradually to the bridge floor with a level stretch of road at each end of the bridge proper.

Earth embankments are held in place by masonry or concrete abutments with or without wings, wood pile supports backed up by planking, or by log cribbing. The sides of the embankment should be sodded to prevent excessive wash. Although there may be a slight settlement in the fill for a time, the embankment will become permanent after a few seasons.

Timber trestles form a cheap and efficient approach to a highway bridge, and if well built of good material protected by preservative treatment will last for a long time. Bridge engineers recognize the value of timber in such locations as shown by the following statements taken from "Bridge Engineering" by J. A. L. Waddell.

"Timber trestles are a very common type of approach to highway bridges, their principal recommendation being their comparatively low first cost." "It is often advisable to use them temporarily (for they can be built quickly as well as cheaply) with the intention of replacing them, before they decay, by earth embankments or steel construction. They can be counted upon to last from 6 to 10 years, but by careful selection of timber, taking special pains in framing and erection, and the expenditure of a little more money (mainly to protect the timber against decay) three or four years more can be added to their life. With the present prices of steel and timber, it is nearly always cheaper to build approaches of wood and replace it with other wood as it decays."

In regard to durability gained by preservative treatment of trestle timbers, Mr. Waddell states further:

"By creosoting or otherwise treating the timber the life of trestles may be increased several fold, and today it is generally best to do so, as an economic study based upon a probable life of twenty-five years for the creosoted material would readily show."

CHAPTER III.

TYPES OF FRAMING.

The framing of a timber highway bridge consists of the main carrying members, which may be either heavy stringers or trusses depending on the size of bridge, the floor system, and the lateral bracing at bottom or top chords if needed.

Types of Bridges Timber highway bridges are ordinarily of the girder, truss, or trestle type, although many timber bridges of the solid arch rib and trussed arch types have been built in the past and found to be satisfactory. Simple bridges are those of the beam, girder or truss type supported at both ends only and used for spans of short or medium length. Continuous bridges continue unbroken over two or more spans. A through bridge has the floor supported by the lower chord, while a deck bridge has the floor supported on or near the top chord of the trusses. A pony truss bridge is a through bridge having trusses so low that no overhead bracing can be used. These trusses are used for short and medium spans but should be braced at the sides of each joint of the top chord to strengthen them laterally. High truss bridges are used for both long and short spans.

Girder bridges consist of heavy timber stringers or joists spaced at intervals of 2 to 2½ feet and supported by capped piles, framed bents, or masonry abutments at the ends. An end sill should always be used in this type of bridge to give all stringers an even bearing. The stringers form a base for the floor planking. Details of bridge floors will be found in Chapter IV.

Trestle bridges are of the continuous type and are divided into two general classes; pile trestles in which the bents consist of capped piles, and framed trestles in which the bents are formed of squared timbers framed together. Pile trestles are generally limited to a height of 30 feet, while framed trestles

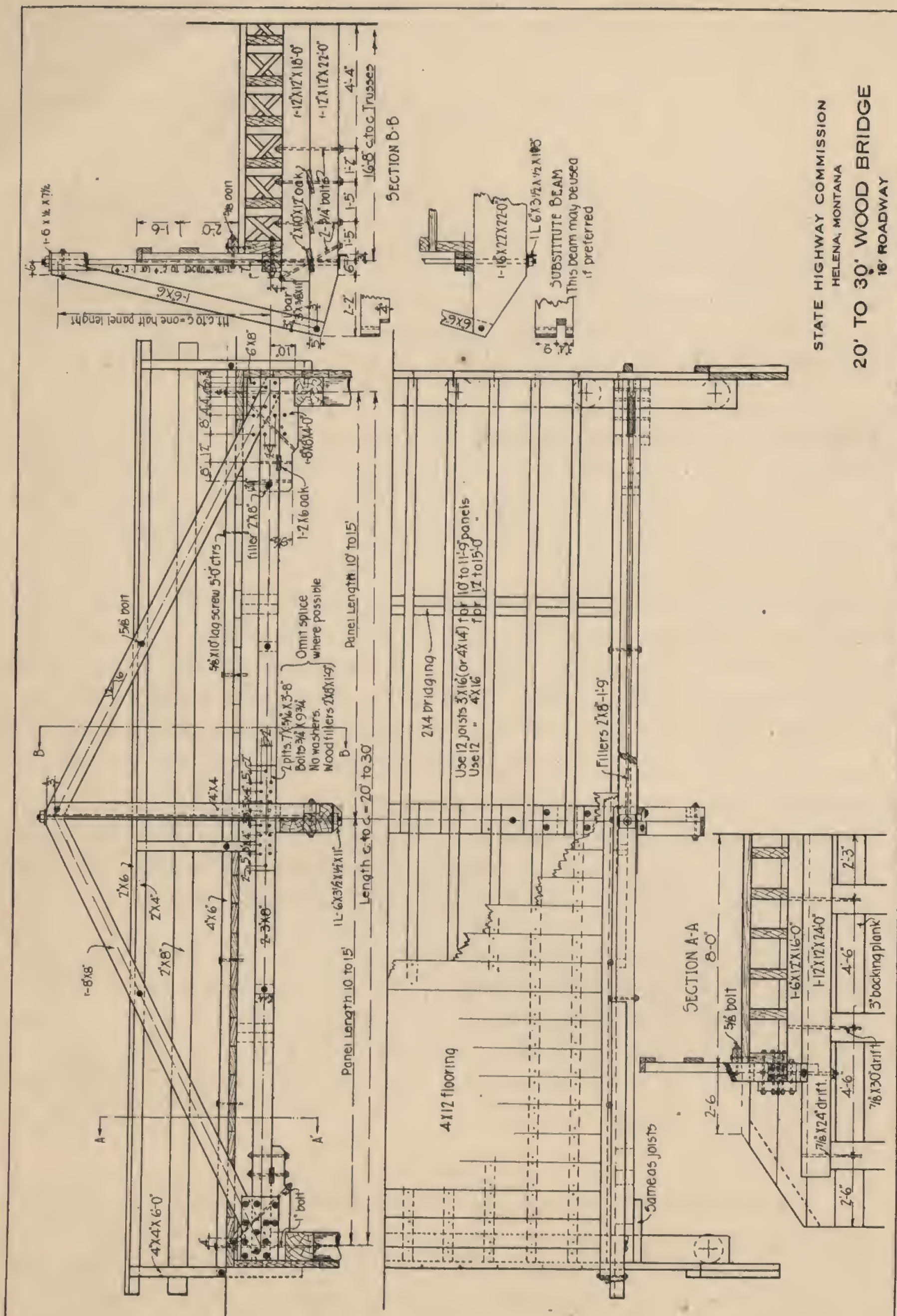


Fig. 3. King-Rod Timber Bridge Truss.

are not limited to height. Framed trestles over 40 feet in height require a special design for economy and safety. Timber trestles were discussed on page 9.

Types of Wooden Bridge Trusses Wooden bridge trusses are generally confined to one of the three types shown in Figs. 3, 4, and 5, although lattice trusses and trussed arch bridges are still built.

The king-rod truss shown in Fig. 3 is one of the simplest forms built and is used over small spans or in connection with a trestle bridge. This truss is generally limited to a span of 24 feet.

The queen-rod truss shown in Fig. 4 is of the same general type as that shown in Fig. 1, but has a horizontal top chord and two vertical ties instead of the one center tie shown in Fig. 1. This truss may be used on spans up to 50 feet if necessary. In each of these cases the upper and lower chord and the braces are made of timber while the vertical ties are of steel or wrought iron.

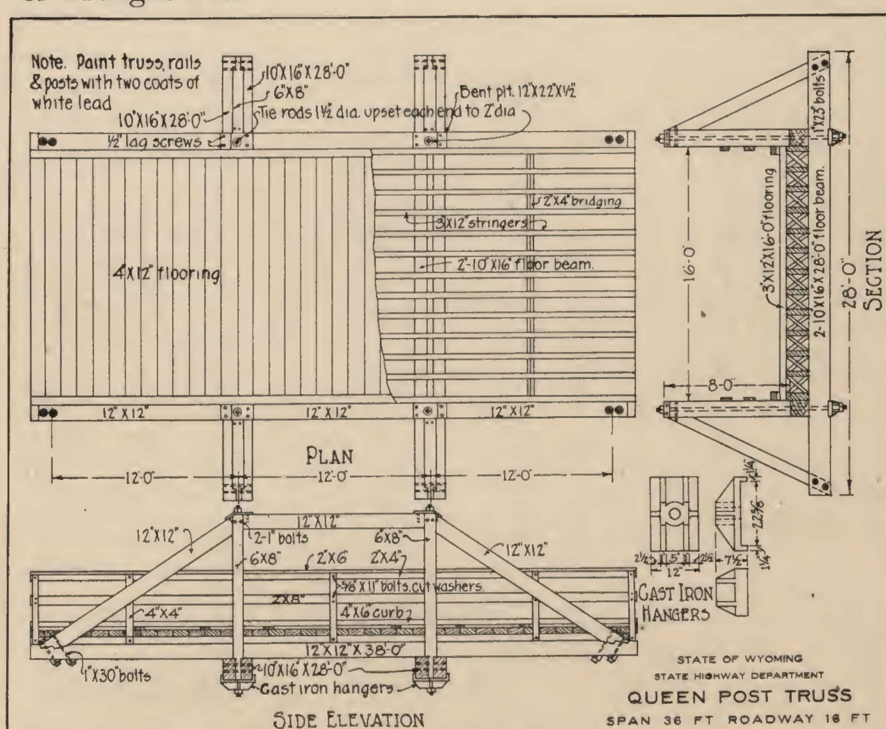


Fig. 4. Queen-Rod Timber Bridge Truss.

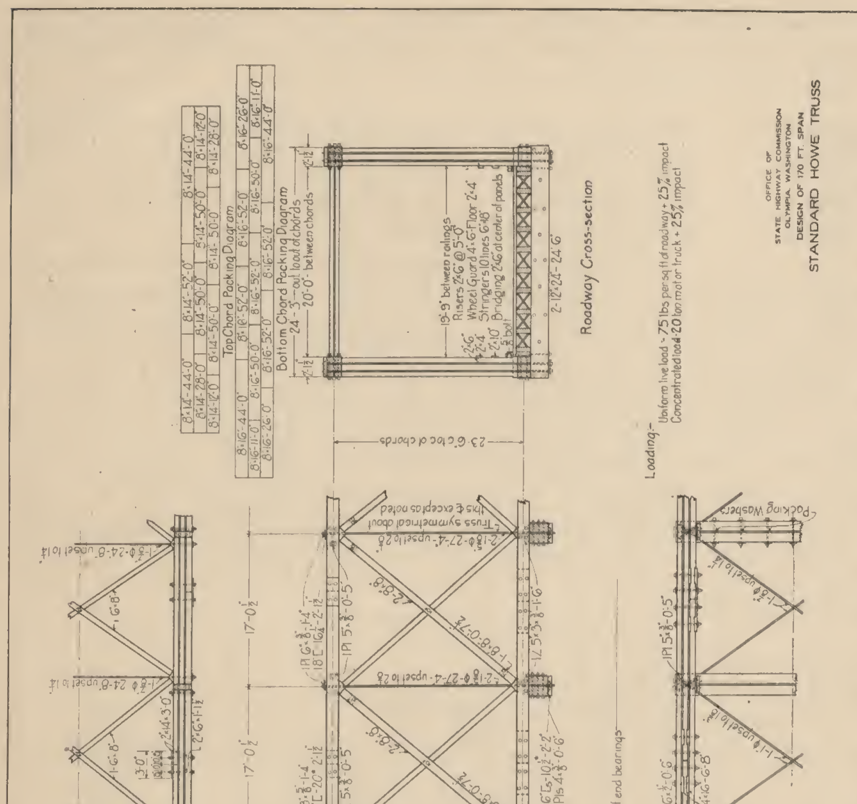


Fig. 5. Howe Truss Timber Bridge.

The rise of the slanting top chord in each of these trusses should never be less than 6 inches in 12 inches while it is claimed that a rise of 8 inches in 12 inches is found to be the most economical.

Large bridge trusses are generally of the Howe type, shown in Fig. 5, and are frequently used for spans up to 150 feet in length. These trusses have the panels braced along both diagonals to withstand the effects of unsymmetrical loading. All members in this truss are of wood except the vertical ties.

In trusses with horizontal top chords as shown in Fig. 5, the height of the truss measured from center of lower chord to center of upper chord should never be less than 1/9 of the span for lengths up to 36 feet, nor less than 1/10 of the span for lengths over 36 feet. The common rule is to make the height from 1/7 to 1/6 of the span for most economical results. The depth of trusses from center to center for through bridges with lateral bracing at the top chords is at least 17 feet in order to allow a clear height of 13 or 14 feet above the floor level. The clear roadway width between trusses will vary from 14 feet in small country bridges up to 20 feet in larger bridges. A clear width of 16 feet is common.

In the Howe truss, the width of the panel is taken as the distance between two adjacent vertical rods or between the outer rod and the end of the truss. In determining the number of panels to use in a given case, the width of each panel should be taken so that the slant of the diagonal braces will lie between 40 to 60 degrees. A common rule for economy is to make the slant about 45 degrees.

The intersection between the center lines of the slanting end member and the horizontal lower chord should be located so that it will always come over the center of the bearing on the end support or pier.

The main girders which support the floor beams should be placed as near the joints of the lower chord as possible, since this concentrates the loads at the joints of the truss and limits the stresses in the members to direct tension or compression. If the loads from the girders are not located at the joints

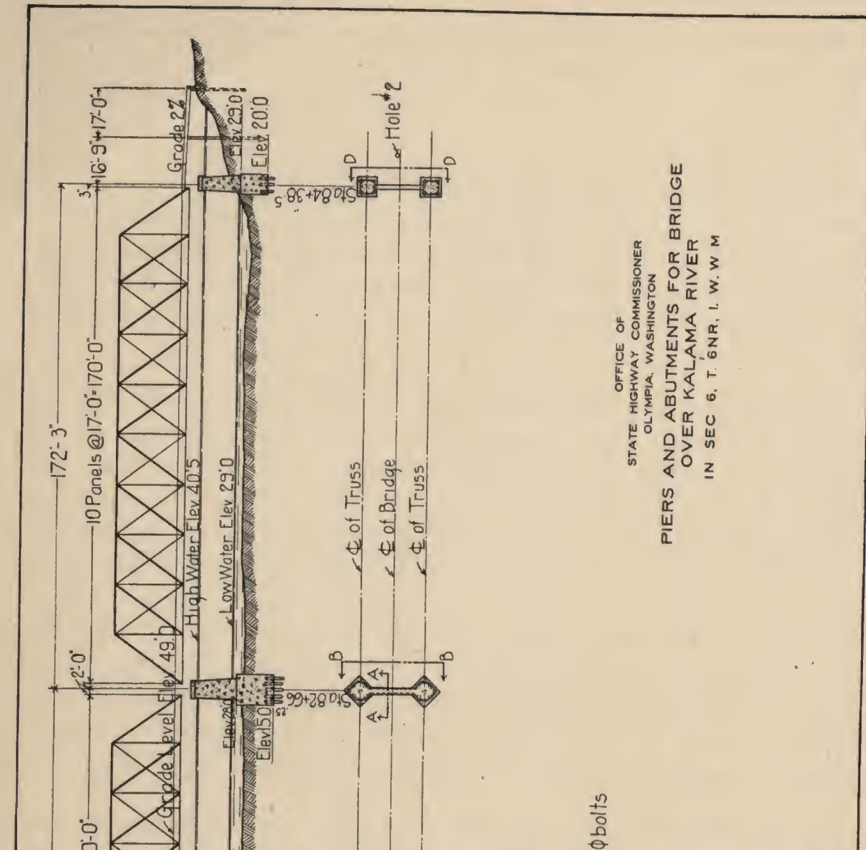


Fig. 6. General View of Highway Bridge Shown in Fig. 5.

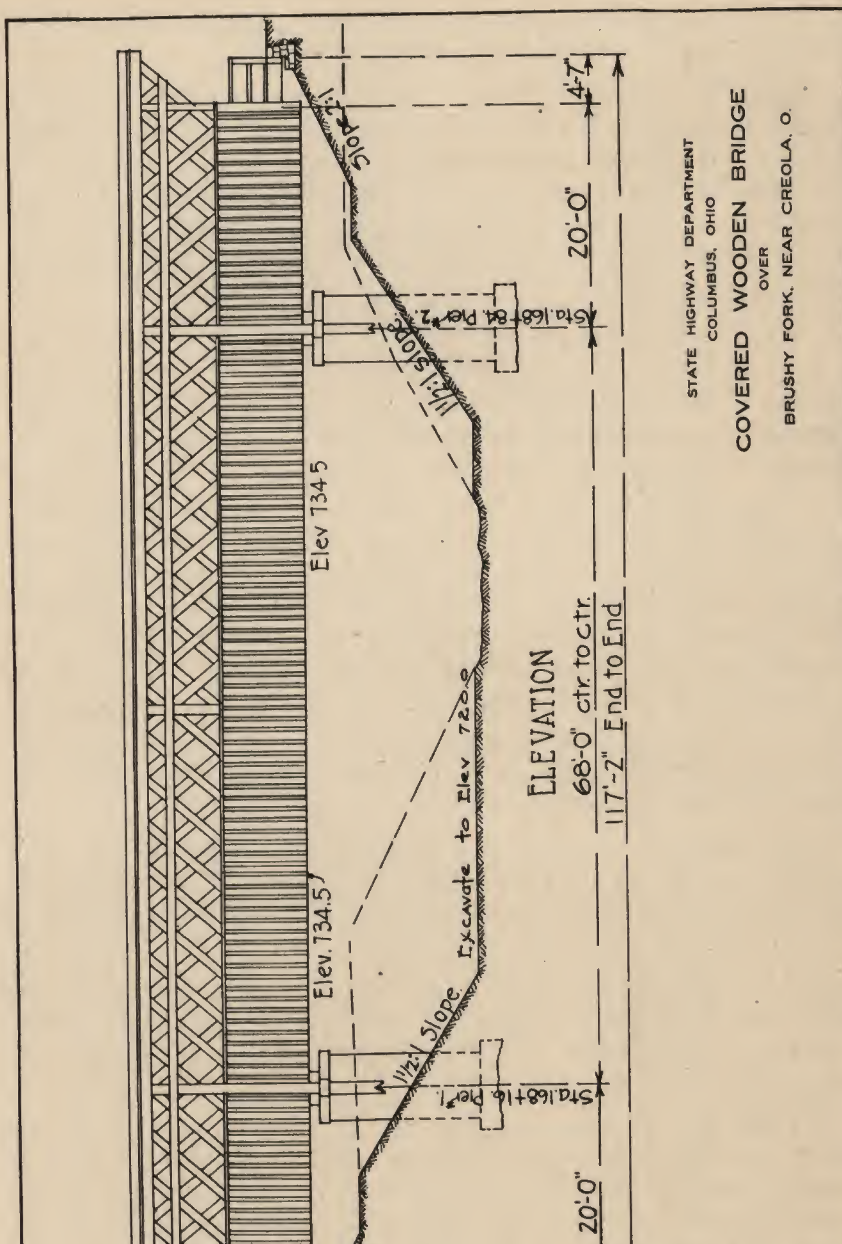


Fig. 7. General View of Covered Highway Bridge Shown in Fig. 26.

of the truss, the chord carrying the load will be subjected to bending stresses as well as to direct stresses.

The lattice type of bridge truss has been used with success for many years. It consists of horizontal top and bottom chords connected by lattice bracing is shown in Fig. 26. All members of this truss may be made of light material, using more than one thickness where needed. The web members are placed with a slant of about 45 degrees and are bolted at each intersection.

Top or Bottom Chords The top and bottom chords of wood trusses may consist of large single timbers in small bridges, or compound members consisting of two to four smaller pieces bolted together. In long spans where it will be necessary to splice the pieces in order to obtain a given length of bridge, the built-up member may be used to an advantage since it allows the use of fairly small sizes of timber and also permits the distribution of the spliced joints over a considerable range of length. Sizes ranging from 3 by 8 inches to 8 by 16 inches are found in many instances. In any case long lengths should be used so as to have as few splices as possible, and not more than one timber should be spliced in the same panel.

The timbers in built-up members are separated by wood packing blocks spaced at frequent intervals as shown in Fig. 8, and all splices should be located at a block. The simplest type of joint for the lower chord, which is a tension member, is the tabled fishplate splice shown in Fig. 13. The joints of the upper chord may be of the ordinary butt type if that member is in pure compression. Types of wood joints are discussed on page 43.

While the stresses vary in the different members of the upper and lower chords of a truss and, therefore, the size of timbers could be different in neighboring panels, it is common practice to use the same size of timber in all panels of the top chord and all panels of the bottom chord. This is not economical design from a stress standpoint, but provides an easy method of splicing members which extend into two or more panels.

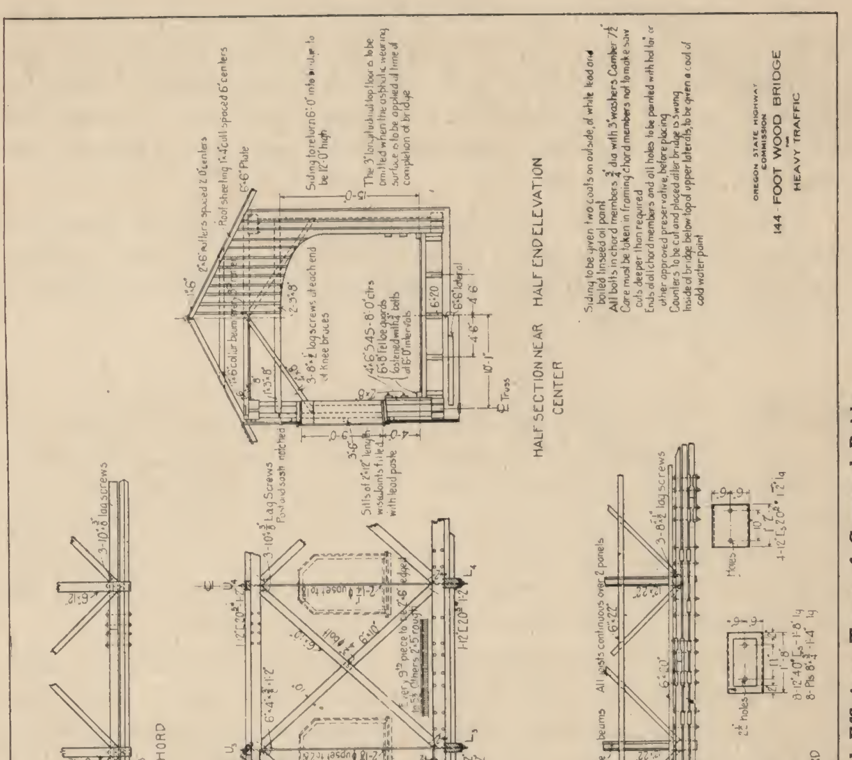


Fig. 8. A Strong and Efficient Type of Covered Bridge.

The built-up members which are in compression should not be figured as single columns unless the packing blocks are located very close together and the member bolted together thoroughly. It is preferable to consider the thrust as distributed equally among the separate pieces and then figure each piece as a separate column.

When the bottom chord supports floor beams along its length instead of locating them at the joints or panel points, the chord should be figured for both bending and direct stresses as referred to above.

Bracing Through bridges of either the Howe or lattice type should be thoroughly braced by systems of laterals at both top and bottom chords. These may consist of pairs of timbers or steel rods fastened at the ends of the floor beams and extending diagonally across each panel, crossing at the middle. Pony truss bridges of the type shown in Figs. 2 and 13 are braced by laterals at the lower chord only.

Timber braces may be notched at the intersection and securely toe-nailed or held together by $\frac{3}{4}$-inch bolts. Details of this type of construction may be found in Figs. 5, 8, and 26. A type of portal bracing is also shown in Fig. 5.

Loads Bridges which are intended for highway traffic only are not subjected to extremely heavy loading. The loads considered in design for ordinary road traffic consist of the dead or fixed loads, the live or movable loads, and the effect of snow or wind. These quantities are all variable and depend upon the type of bridge, the community to be served, and the section of the country in which it is built.

The dead load includes the weight of the trusses, girders, stringers, beams, top and bottom lateral bracing, and the floor system. Although the weight of the trusses and the members which are to be designed is not known in advance, it is usual to assume a weight for such members based upon similar finished bridges and check back after the various sizes have been found. The weights of materials commonly used in timber highway bridge construction may be taken from the following table:

Approximate Weights of Bridge Materials

Asphalt Pavement, including Binder	120	lbs. per cu. ft.
Brick Pavement	140	" " " "
Cast Iron	450	" " " "
Concrete	140-160	" " " "
Creosoted Wood Blocks	50	" " " "
Earth	100	" " " "
Gravel	120	" " " "
Steel	490	" " " "
Timber (Air-Dry):*		
Cedar	24	" " " "
Cypress	34	" " " "
Fir, Douglas	34	" " " "
Hemlock	32	" " " "
Larch	36	" " " "
Oak	47	" " " "
Pine, Norway	34	" " " "
Pine, Southern	40	" " " "
Pine, White	30	" " " "
Spruce	27	" " " "
Tamarack	38	" " " "
Timber, Creosoted	40-50	" " " "

*Averages from Bulletin No. 552, United States Department of Agriculture.

Live loads to be used in the design of highway bridges usually are stated in terms of load per square foot of bridge floor surface. Another consideration is the effect of concentrated live loads due to a road roller, traction engine or a loaded motor truck. It is possible that a combination of these two kinds of load may be needed in a given case, although it is not probable that two loaded trucks or heavy machines will be on the bridge at the same time.

The load due to a crowd of people may vary from 80 to 180 pounds per square foot of floor surface depending on the crowded condition of the bridge. A higher value should be used for short bridges than for long ones since the short bridge is more likely to be crowded. This amount is prescribed by law in some states, otherwise it is determined by the designer or taken from standard specifications for highway bridges. Among the best of the so-called standards are those by J. A. L Waddell, Theodore Cooper, and M. S. Ketchum. In any case the designer should see that the actual conditions of loading likely to occur on the bridge agree with the loading advised for a given classification.

While a load of from 6 to 12 tons formerly was supposed to represent the weight of a traction engine used in farm work, modern engines may weigh as much as 30 tons. A loading of 15 to 20 tons is now used in many localities to meet present conditions in designing the floor system.

A specification given in the American Civil Engineers' Pocket Book, assumes for the floor and its supports, a load of 80 pounds per square foot of total floor surface or 6 short tons on two axles 10 feet centers and 5 feet gage. For trusses, 80 pounds per square foot of total floor surface for spans up to 75 feet, and 55 pounds for spans 200 feet and over; proportionally for intermediate spans. Where a steam road roller is likely to be used on a bridge, provision must be made for it in the design. The heaviest rollers have the following loads and dimensions: total weight 30,000 pounds; weight on front wheel 12,000 pounds, and on each of two rear wheels 9,000 pounds; width of front wheel 4 feet, and of each rear wheel 20 inches; distance between front and rear axles 11 feet; center to center rear rollers 5 feet.

M. S. Ketchum assumes the following loadings in his Specifications for Steel Highway Bridges:

"*Heavy Country Bridges.*—For the floor and its supports, a load of 100 pounds per square foot of total floor surface or a 20-ton traction engine with axles 11 feet centers and 7 feet gage, four-fifths of the load to be carried on the rear axles."

Loads for the trusses are assumed as 80 pounds per square foot of floor surface for bridges up to 100 feet in span. This loading diminishes 1 pound per square foot for each additional 5 feet of span up to 200 feet when a value of 60 pounds per square foot is reached. This value is used for all spans over 200 feet. No bridge to be designed for a load less than 1,000 pounds per lineal foot of bridge.

"*Ordinary Country Bridges.*—For the floor and its supports, a load of 80 pounds per square foot of total floor surface or a 15-ton traction engine with axles 10 feet centers and 6 feet gage, two-thirds of the load to be carried on the rear axles."

Loads for the trusses are assumed as 75 pounds per square foot of floor surface for bridges up to 100 feet in span. This loading diminishes 1 pound per square foot for each additional 5 feet of span up to 200 feet when a value of 55 pounds per square foot is reached. This value is used for all spans over 200 feet. No bridge to be designed for a load of less than 800 pounds per lineal foot of bridge.

The increasing load capacity of motor trucks is approaching that of the road roller, while the effect of motor truck or

other moving loads makes necessary an allowance for impact which is not common with the slower moving roller. Some of the empirical formulas for impact factor give a value of over 40 percent, but 25 percent is a common factor in use among highway engineers.

The snow load will vary in different parts of the country, but an allowance of 20 pounds per square foot is an ordinary value taken for a maximum. In extremely cold, stormy climates, it may be necessary to estimate the snow load on an open or covered bridge on the basis of 50 pounds per cubic foot for compacted snow. Some designers make an allowance for snow in choosing a value for the uniformly distributed dead load.

The wind load is taken as acting horizontally in either direction. A rule given in the American Civil Engineers' Pocket Book assumes 30 pounds per square foot on exposed surfaces of all trusses and the floor as seen in elevation, and 150 pounds per linear foot of span; or 50 pounds per square foot on all exposed surfaces of the unloaded bridge. The greater calculated stress is to be used in designing the wind bracing.

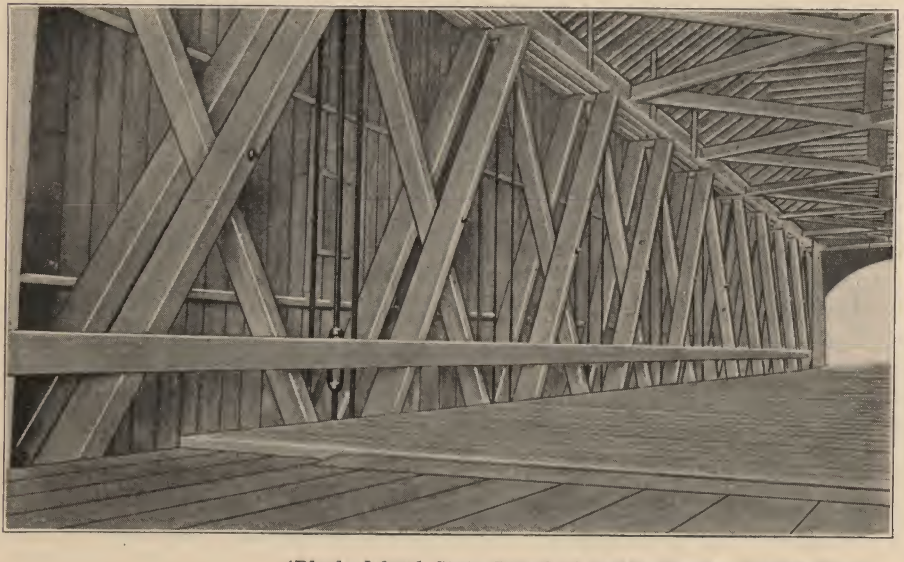
Ketchum's Specifications for Steel Highway Bridges state that the bottom lateral bracing in through bridges shall be designed to resist a lateral wind load of 300 pounds per foot of span, 150 pounds of this to be treated as a moving load. The top lateral bracing should resist a lateral wind load of 150 pounds for each foot of span. In bridges with sway bracing, one-half of the wind load is assumed to pass to the lower chord through the sway bracing.

Stress in Timber Trusses The amount of stress to be resisted in the various members of a timber truss can be found either graphically or by analytical methods after the loading is determined. Such methods and details are described in engineering handbooks or books relating to structural design. All parts of a bridge should be designed to resist safely the stresses produced by all probable combinations of the loadings described above. An experienced engineer or designer should make or direct all calculations because of the importance of such structures. There are several reliable books which contain information on loads and combinations of load-

ing for highway bridges, but the detail is of too large volume to attempt here. A list of valuable references will be found at the end of this bulletin.

Covered Bridges Many of the older and a few of the recent timber highway bridges are covered or housed in to protect the timbers and shelter the roadway. Examples of such structures are shown in Figs. 7 and 8. Covered bridges may be found in Ohio, Virginia, Maryland and other eastern states which were built from fifty to one-hundred years ago and are still giving excellent service. Many of these old bridges were designed for a 6-ton floor load and have been strengthened to meet the heavier loading of the present day. If the floor systems of these bridges were of heavier material, it is claimed that some of them would stand service for fifty years more.

Covered bridges have been condemned by the public in many instances on account of the material used for the covering. It is poor economy to use a cheap housing put on in a loose, careless manner. The barn-like appearance of some of these bridges has also been criticized, but this fault can be corrected easily by the designer as shown in the illustrations.



(Rhode Island State Board of Public Roads—Bridge Dept.)

Fig. 9. Interior of Covered Bridge.

CHAPTER IV.

FLOORS AND WEARING SURFACES.

The floor of a highway bridge consists of the main carrying members such as beams, stringers or joists, floor planking, and any other material used as a wearing surface over the planking. The planking is held in place by the stringers which extend in the direction of the length of the bridge. In small beam bridges the stringers may be all the floor framing that is needed. In truss bridges, the stringers or joists rest on large timber beams extending from truss to truss and supported at opposite joints or panel points. Both untreated timbers and timber which has been given preservative treatment are used in bridges and bridge floors, but treated timbers will give longer and better service.

The life of ordinary timbers may be prolonged by giving all contact surfaces where wood rests on wood, masonry, or metal a thorough brush treatment with a recognized preservative before installation. This applies to holes for rods and bearings for bolt heads or washers as well as to main bearing surfaces. While these surface coatings do not produce the results obtained by the use of thoroughly treated timbers, they are far better than no treatment at all. Some engineers recommend that the creosoted surfaces be given a coating of asphalt or tar to hold the creosote in place, but the value of this coating is doubtful.

If treated timber is used, all holes and cut surfaces made or exposed after treatment should be protected with preservative before the timber is put in place. Preservative treatment for timber will be discussed in Chapter VII.

Floor Beams When floor beams are used between trusses, they are supported at the joints of the lower chord by metal hangers as shown in Fig. 5. In lattice trusses, similar to Fig. 26, the beams are placed on the top of the lower chord. The type of beam used varies with the structure and the load to be carried by one beam. Beams for heavy loads

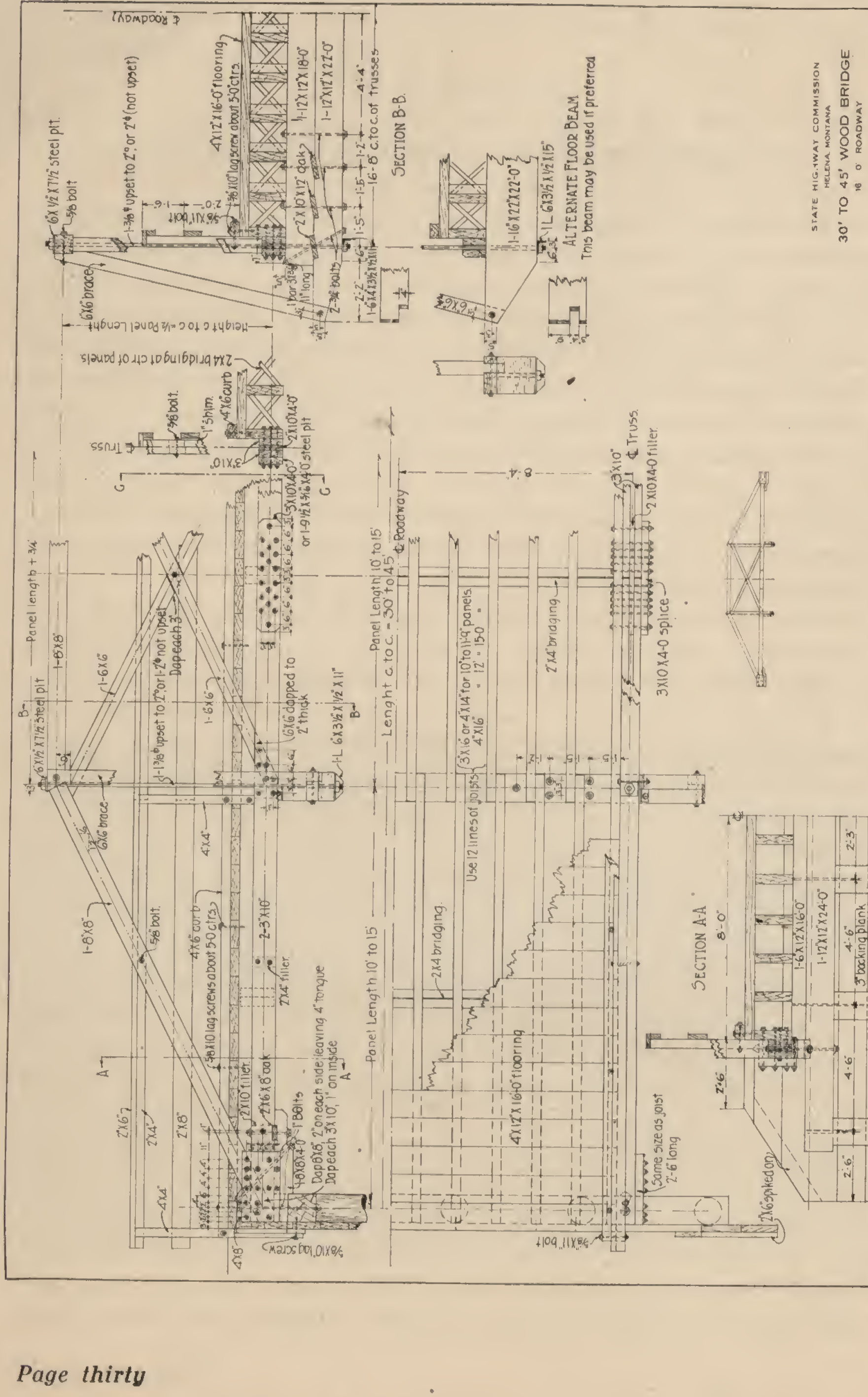


Fig. 10. Use of Compound Keyed Beams in Bridges.

consist of large timbers used singly or in pairs. When used in pairs they are generally bolted together side by side, but in some instances one has been placed on top of the other, bolted and keyed, thus making a deep beam of good strength. A beam of this type is shown in Fig. 10. For light loads or small spacing of beams, a small single timber may be used. If it is difficult to obtain large timbers for stringers or beams, a very satisfactory substitute consists of built-up timbers made from stock 2 or 3 inches in thickness set on edge and fastened together by 3/4-inch bolts spaced about 2 feet on centers and staggered along the length of the member. Two bolts should be used at each end, and all bolts should be at least 2 inches in from the edge of the timber. Cast iron washers 3 inches in diameter should be used under the head and nut of each bolt.

The size of timber floor beams and stringers may be found by the formula for beams of rectangular cross-section and should be large enough to support the probable load with an allowance for impact. The value of the maximum bending moment should be found from the loading likely to come on the structure, and an allowable working strength taken to correspond to the kind of timber used. It will be necessary to choose one dimension and solve for the other.

Methods of finding values for bending moments may be found in engineers' handbooks or in the reference books given at the end of this bulletin. The table of unit stresses for timber shown on page 32 was taken from the 1915 Manual of the American Railway Engineering Association, Report of Committee VII, Wooden Bridges and Trestles.

Stringers The stringers or joists support the floor planking and extend between floor beams in a truss bridge, or between caps in a trestle bridge. They are placed on the top of these main carrying members with the ends lapping across the entire width of the support and dapped at least 1/2 inch to bring the top surfaces to an exact level for the planking. An air space of 1/2 inch is left between the ends for ventilation.

A minimum width or thickness of 3 inches and depth of 12 inches, or four times the thickness, is often specified for roadways. If the depth of the stringers is greater than four times the thickness, it is advisable to use bridging at intervals

WOODEN BRIDGES AND TRESTLES

WORKING UNIT-STRESSES FOR STRUCTURAL TIMBER EXPRESSED IN POUNDS PER SQUARE INCH.

NOTE—The working unit-stresses given in this table are intended for railroad bridges and trestles. For highway bridges and trestles the unit-stresses may be increased twenty-five (25) per cent. For buildings and similar structures, in which the timber is protected from the weather and practically free from impact, the unit-stresses may be increased fifty (50) per cent. To compute the deflection of a beam under long-continued loading instead of that when the load is first applied, only fifty (50) per cent of the corresponding modulus of elasticity given in the table is to be employed.

Kind of Timber	Bending			Shearing				Compression						Ratio of Length of Stringer to Depth
	Extreme Fiber Stress		Modulus of Elasticity	Parallel to the Grain		Longitudinal Shear in Beams		Perpendicular to the Grain		Parallel to the Grain		For Columns under 15 Diams. Working Stress	Formulas for Working Stress in Long Columns over 15 Diams.	
	Average Ultimate	Working Stress	Average	Average Ultimate	Working Stress	Average Ultimate	Working Stress	Elastic Limit	Working Stress	Average Ultimate	Working Stress			
Douglas Fir	6100	1200	1,510,000	690	170	270	110	630	310	3600	1200	900	1200 (1-1/60d)	10
Longleaf Pine	6500	1300	1,610,000	720	180	300	120	520	260	3800	1300	980	1300 (1-1/60d)	10
Shortleaf Pine	5600	1100	1,480,000	710	170	330	130	340	170	3400	1100	830	1100 (1-1/60d)	10
White Pine	4400	900	1,130,000	400	100	180	70	290	150	3000	1000	750	1000 (1-1/60d)	10
Spruce	4800	1000	1,310,000	600	150	170	70	370	180	3200	1100	830	1100 (1-1/60d)	..
Norway Pine	4200	800	1,190,000	590*	130	250	100	...	150	2600*	800	600	800 (1-1/60d)	..
Tamarack	4600	900	1,220,000	670	170	260	100	...	220	3200*	1000	750	1000 (1-1/60d)	..
Western Hemlock	5800	1100	1,480,000	630	160	270*	100	440	220	3500	1200	900	1200 (1-1/60d)	..
Redwood	5000	900	800,000	300	80	...	...	400	150	3300	900	680	900 (1-1/60d)	..
Bald Cypress	4800	900	1,150,000	500	120	...	...	340	170	3900	1100	830	1100 (1-1/60d)	..
Red Cedar	4200	800	800,000	...	...	...	...	470	230	2800	900	680	900 (1-1/60d)	..
White Oak	5700	1100	1,150,000	840	210	270	110	920	450	3500	1300	980	1300 (1-1/60d)	12

These unit-stresses are for a green condition of timber and are to be used without increasing the live load stresses for impact.

*Partially air-dry. l—Length in inches. d—Least side in inches.

not exceeding 8 feet along the length of the stringer. Common sizes of roadway floor joists are 3 by 12 inches, 3 by 14 inches, 4 by 14 inches, and 4 by 16 inches. Joists for sidewalks may be the same as those of the main roadway in small structures. In larger structures with an independent sidewalk, the sizes are commonly 2 by 12 inches, 3 by 12 inches, or 3 by 14 inches.

The maximum spacing of stringers or joists varies in different specifications from 2 or 2½ feet on centers up to a spacing in feet equal to the thickness of the main floor planking in inches. This latter rule ordinarily gives too great values for use with heavy traffic. The outside stringers butt together at the ends so as to allow a continuous surface along the length of the span or bridge, except in truss bridges where the members of the lower chord form the outside stringers. If floor planks thicker than 3 inches are used, it will not be necessary to fasten the joists to the floor beams or to use bridging unless the joists are very deep.

Decay may occur in floor joists where the planking rests on them. If deep joists are used, they may be turned over when the top surface has become slightly affected and the solid under-surface used to hold the planking. The solid depth should still be sufficient to carry the load safely. Decay may be prevented or retarded by the use of treated timber or by giving the contact sufaces a thorough brush treatment with preservative.

Planking The main planking for bridge floors may be laid flat on the stringers or stood on edge as in floors of the laminated mill construction type. This main floor is used alone in some bridges, and covered with a wearing surface of thinner planking, creosoted wood blocks or a mixture of gravel and bituminous material in other cases.

The planks which form the main roadway should be at least 3 inches thick and not over 10 inches wide. Specifications vary in the best widths to be used, but the range is commonly between 6 and 10 inches. They should be laid transversely or diagonally across the stringers with the heart side down, and spaced about ¼ inch apart, except in the case of material treated with a preservative, which may be laid with close joints.

If a plank wearing surface is used, the lower layer consists of material which has been given preservative treatment laid diagonally or transversely, with the top layer extending across the bridge in a direction different from that of the main planking. An angle of 45 to 60 degrees between the two directions is common. Flat-grained planks in the wearing surface should never be laid lengthwise in the direction of travel. Some specifications require a minimum thickness of $2\frac{1}{2}$ inches for the main planking and state that it shall be laid diagonally with $\frac{1}{2}$-inch spaces between planks; the wearing surface to be $1\frac{1}{2}$ inches thick. Others allow main planking from 2 to 4 inches in thickness, depending upon the loading, with a wearing surface 2 inches thick. The main floor should be fastened to the joists with two nails at each joist, and the wearing planks nailed to the main floor every 2 feet with two nails. A double floor should have the contact surfaces planed, and all planks in both floors sized to a uniform thickness. The planks in this type of floor should also be laid with the heart side down.

The planking for sidewalks or footwalks should be at least 2 inches thick and about 6 inches wide, spaced with $\frac{1}{2}$-inch openings. All planking in footwalks, main floors and wearing surfaces should have a full and even bearing on the joists or stringers and be firmly nailed or spiked to them.

Specifications vary in the size of spikes or nails for holding the planking of roadway and sidewalk floors to the joists. A common rule is to use two 60d. spikes or 6-inch wire nails at each joist or stringer in planking $2\frac{1}{2}$ to 4 inches thick. For planking under $2\frac{1}{2}$ inches, two 40d. spikes or 5-inch wire nails per joist, and for planking 4 inches in thickness, 7-inch nails. Some engineers advocate the use of 7-inch nails or spikes with 3-inch planking in a single thickness floor. If cut spikes are used, it is advisable to bore holes in the timber to prevent splitting.

Laminated Floors The laminated type of floor is used in two different ways on bridges. The ordinary method of planking may be replaced by 2 by 4-inch stock placed on edge and spiked together every 2 feet with 16d. nails. This flooring is fastened to the stringers with 20d. nails. In some cases the pieces of flooring are treated with a preservative on the sides which are placed in contact to prevent

decay. The vertical grain of the wood is exposed to wear, and it is claimed that this type of floor will remain smooth at all times and will outlast at least three plank floors laid in the ordinary way if the wear comes directly on the main planking.

The other method is to do away with the joists or stringers of the ordinary floor by using heavy planks set on edge and spiked together closely to form a self-supporting timber slab between floor beams or bents. The thickness of this floor will depend upon the load to be carried and the distance between beams or bents. A wearing surface of wood blocks is laid on top of the planking. This type of construction results in a strong, rigid floor at a low cost.

The first cost of bridge floors made of timber that has been given preservative treatment will be greater than for floors of untreated material, but the increase in the length of service without repairs will more than offset the difference in cost. A discussion of preservative treatment will be found in Chapter VII.

Wood Block Paving

Creosoted wood blocks make an ideal wearing surface for bridge floors where a double floor is needed. Both treated and untreated plank sub-floors are used to support the block wearing surface, but it is advisable to use material which has been thoroughly treated with a recognized preservative.

The specifications for materials to be used and method of laying wood block floors on bridges are similar to those used for street work. In timber bridges, the concrete base and sand cushion are omitted and a bituminous coating, bituminous felt, or tarred paper layer substituted.

Upon the bed thus prepared the blocks should be set with the fiber of the wood vertical in straight parallel courses, leaving a space next to the curb 1 inch in width for the expansion joint.

The blocks should be laid by setting them hand-tight on the base or cushion; no joint to be more than 3/16 inch in width. They may be driven together every ten courses to keep the rows straight. Nothing but whole blocks should be used, except in starting a course, or in such other cases as the purchaser may direct; and in no case should the lap joint be less than 2 inches.

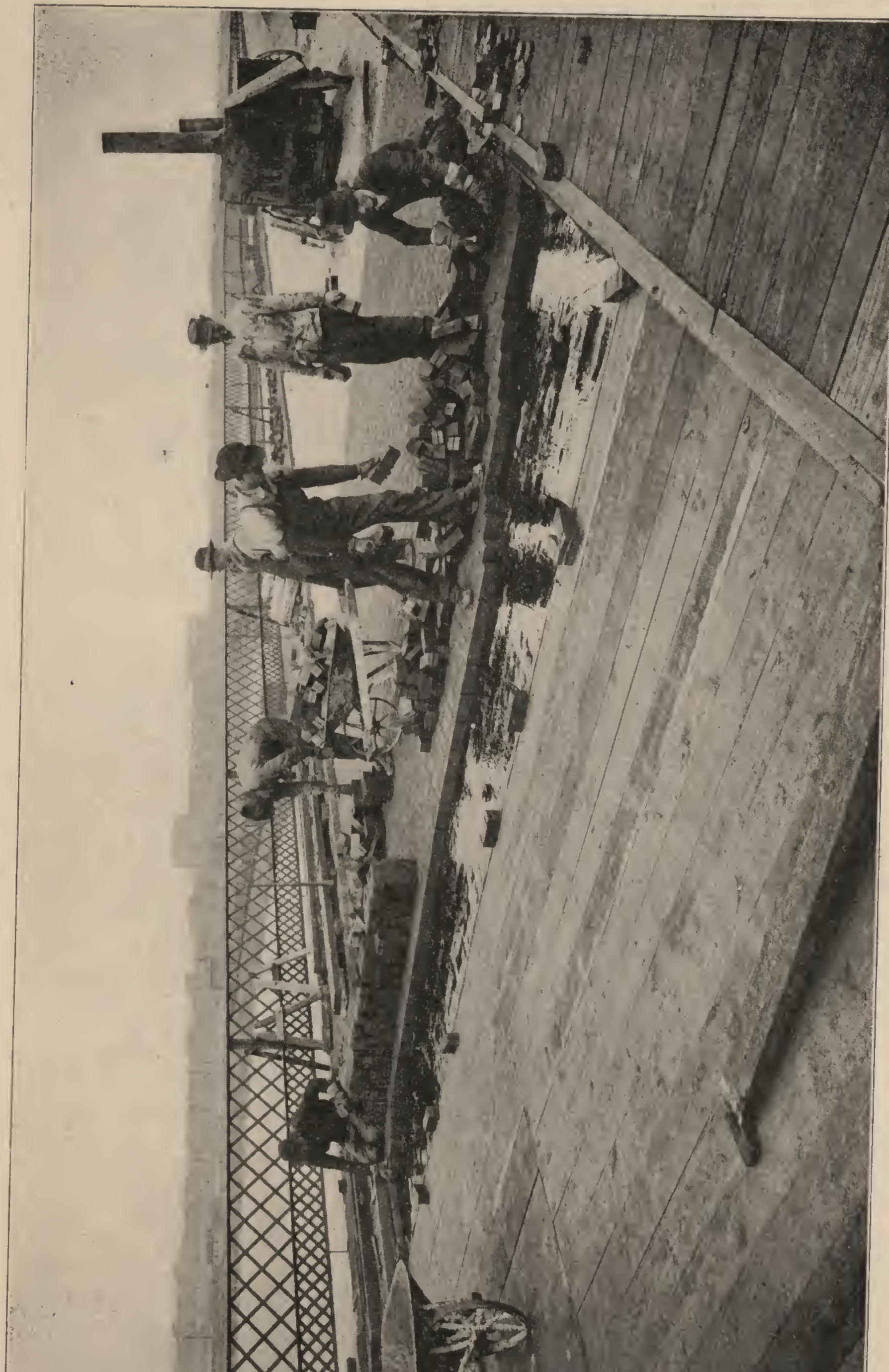


Fig. 11. Method of Laying Creosoted Wood Blocks for Wearing Surface.

Closures should be carefully cut and trimmed by experienced men.

The angle, of course, to the curb should be fixed at the discretion of the purchaser.

After the blocks are placed on the bed they should be rolled parallel and diagonally to the curb by a tandem roller weighing between 4 and 7 tons until the surface becomes smooth and is brought truly to the grade and contour of the finished pavement.

After the rolling is completed the joints between the blocks should be filled with a bituminous filler. This is preferably done only when the temperature of the air is above 45° F. The filler should be brought to the proper temperature and poured into the joints; and filler on the surface of the pavement must be spread as thinly as possible by means of squeegees. The filler should be thoroughly worked into the joints between the blocks while hot, leaving no surplus on the pavement.

The surface should then be completely covered to a depth of about one-half inch with clean, coarse, dry sand, which should be left upon the pavement.

Experience has shown the importance of a rigid floor for supporting the blocks, also the advantage of a cushion layer between the blocks and floor. The Illinois Highway Department has found that satisfactory results are obtained by using 3-inch creosoted plank laid on stringers spaced from 2 to 2½ feet apart. The plank floor is mopped with a bituminous coating and covered with a ¼-inch layer of bituminous felt. This felt layer is then mopped with a bituminous coating before the blocks are laid.

The kind of timber most commonly used for paving, the kind of preservative to use, approved methods of treatment, together with the size of blocks are stated in the Specifications for Creosoted Wood Block Paving, Revised and Adopted by the American Wood Preservers' Association, January 25, 1917.

The Paving Block Committee of the Southern Pine Association has recommended the following specification for timber to be used for wood blocks.

"*Timber.*—The wood to be treated shall be southern pine, cut from live standing trees, and subject to inspection at the creosoting plant before

being sawed and at any subsequent stage of manufacture. The blocks must be sound, and must be well manufactured, square-butted and square-edged, free from unsound, loose or hollow knots, knot holes, worm holes and other defects, such as shakes and checks, that would be detrimental to the life of the blocks.

"The number of annual rings in the first inch which begins 2 inches from the pith of the block shall not be less than six, measured radially, provided, however, that blocks containing between five and six rings in this inch shall be accepted if they contain 33⅓% or more of summer-wood. In case the block does not contain the pith, the 1 inch to be used shall begin 1 inch away from the ring which is nearest to the heart of the block. The blocks in each charge shall contain an average of at least 70% of heart-wood. No one block shall be accepted that contains less than 50% of heart-wood.

"The blocks shall be from 5 to 10 inches long, and should preferably average two times the depth; they shall be* .... inches in depth. They may be from 3 to 4 inches in width, but in any one city block all of them shall be of uniform width. A variation, from that specified, of 1/16 of an inch shall be allowed in the depth, and ⅛ inch in the width of the blocks. In all cases the width shall be greater or less than the depth by at least ¼ inch."

*NOTE.—For very heavy traffic the blocks should be 4 inches in depth, for moderate traffic 3½ inches, and for light traffic 3 inches in depth, but where the 3-inch blocks are used no block shall be longer than 8 inches.

Gravel Wearing Surface Floors consisting of a plank sub-floor with a wearing surface about ¾ inch thick composed of a mixture of gravel or stone chips and bituminous material have been used with success. Shiplap planking makes a cheap, tight floor and prevents the leakage of the binding material. Mastic surfaces can be maintained by an occasional surface application of bituminous material and grits, and if properly attended to, it is claimed that an ordinary, uncreosoted oak floor will last at least ten years.

Wheel Guards Wheel or felloe guards are used in many instances to limit the path of travel of vehicles on the bridge. These guards consist of a timber strip about 4 by 6 inches or 6 by 8 inches in size extending the entire length of the structure on each side of the roadway. They are held in place by bolts, and are either in direct contact with the bridge floor or raised about 2 inches above it by washers or blocks located at the bolts.

The type of construction often specified is as follows:

Wheel guards of a cross-section not less than 6 by 4 inches shall be provided on each side of the roadway. They shall be blocked up from the floor plank with blocks 2 inches by 6 inches by 12 inches long, not over 5 feet apart center to center, held in place by one ¾-inch bolt passing through the center of each blocking piece and securely fastened to the stringer below. The wheel guards shall be spliced over a blocking piece with half and half joints with a 6-inch lap.

A more complete specification is given by J. A. L. Waddell in his work on Bridge Engineering:

"There shall be a wheel-guard of a scantling not less than four (4) inches by six (6) inches on each side of the roadway to prevent wheel hubs from striking the trusses. It is to be laid on its flat, and blocked up from the floor by shims at least one (1) foot long, six (6) inches wide, and two (2) inches thick, spaced not more than five (5) feet between centres, each shim being spiked to the floor by four (4) four and a half (4½) inch cut spikes. The guard-rails are to be bolted to the floor through the centre of each shim by a three-quarter (¾) inch bolt, which must also pass through the joist beneath. When the guard-rails are bolted to the wooden hand-rail posts, the bolt-heads are to be countersunk into the guard-rail, so as to make a flush surface on the inner face of same. The joints in the guard-rail are to be lap-joints, at least six (6) inches long, each located symmetrically over the middle of a shim. When a bridge is on a heavy grade, the inner, upper corners of the guard-rails are to be covered with steel angles fastened to the timber by counter-sunk screws, spaced about eighteen (18) inches apart, so as to protect the guard-rails from the injurious effects of using them instead of wheel-brakes for heavily loaded wagons."

It is claimed that the use of these guards may cause decay to occur in untreated floor planks at the guard and make necessary the replacement of planks while they are sound at other parts. This is due to dirt which collects along the timber and holds moisture for a time, or to continued dampness from rain which seeps under the guard. Raising the timber from the floor still provides a space for the collection of dirt and, therefore, may cause decay. For this reason it seems advisable to omit wheel guards where untreated flooring is used unless they are absolutely necessary. If they are placed on an untreated floor, the danger of decay can be lessened by giving the under side of the guards and the top of the planks at the contact surface at least two thorough coats of coal-tar creosote oil or other recognized preservative when the guards are bolted in place. A creosoted wood block floor would not be subject to this objection.

Sidewalks and Railings Sidewalks or footwalks may be needed at one or both sides of more important bridges, although it is not common to allow for such space in the ordinary country highway bridge. They may be separated from the main roadway in trestle bridges by high wheel guards, but in truss bridges they are supported on joists or stringers carried either by an extension of the floor beams at the joints of the truss, or by brackets located at those points. The planking is lighter than for the main roadway as stated in the preceding pages.

Railings or hand rails should be used on each side of a highway bridge. These must be of strong construction and high enough to prevent accidents or to keep horses from jumping over. This height will vary from $3\frac{1}{2}$ to 5 feet above the floor level.

Railings should be supported by 4 by 4-inch or 4 by 6-inch posts located preferably not over 8 or 10 feet apart. The spacing of the floor beams may make a greater distance between main supports necessary in truss bridges and in such cases, an intermediate support should be used at the middle of each panel. These posts should be firmly attached to the bridge timbers and braced in a rigid manner. If attached to the joists or stringers of the bridge floor, the joists should be held firmly by bridging. Details showing method of support and bracing are shown in Figs. 12 and 20.

The railing should consist of at least a line of top rail and a hub plank for heavy traffic. The top rail is formed by placing a line of 2 by 6-inch timbers flat on the top of the posts with another line of 2 by 4-inch or 2 by 6-inch material set on edge underneath to form a support for the flat planks between posts. The hub planks vary in size from 2 by 6-inch to 2 by 12-inch stock, and are located about half way between the floor level and the top of the rail.

Drainage of Floors The common method of draining bridge floors which are covered with a wearing surface is to crown the roadway enough to allow the water to run to the sides. A single layer of planking will drain itself through the spaces between planks. If specifications call for

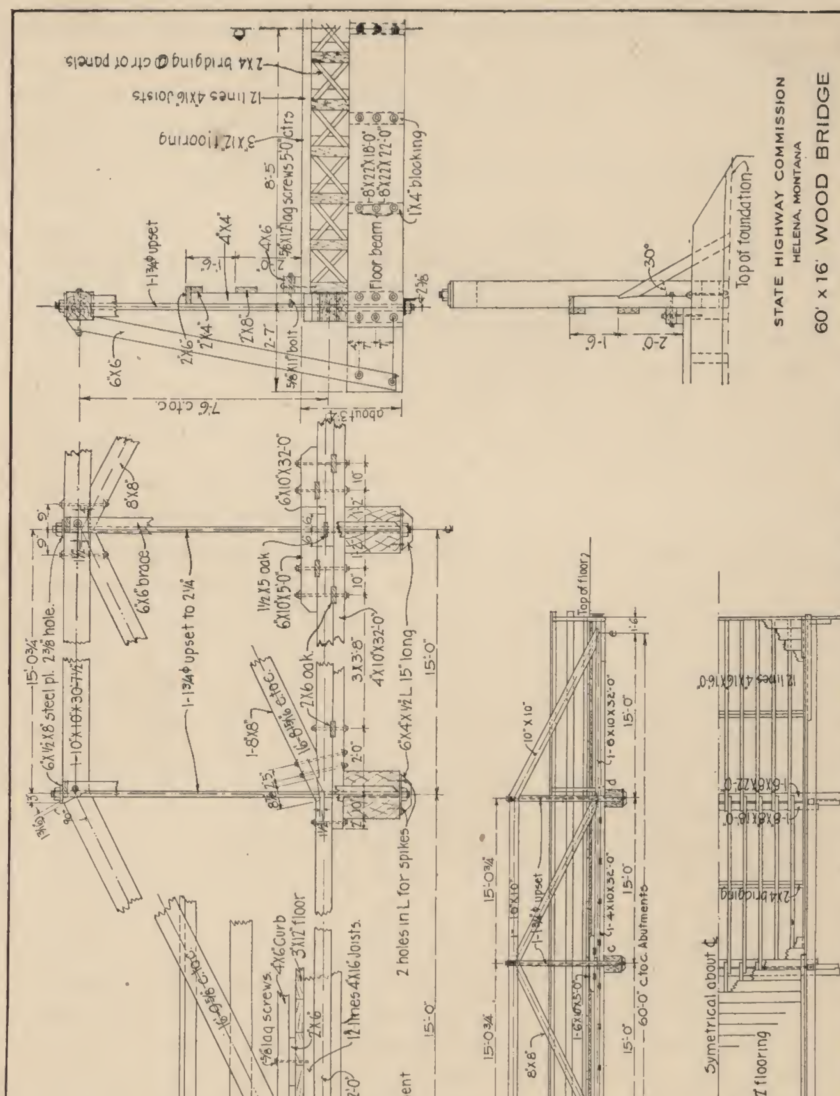


Fig. 12. Detail of Truss Bracing and Railing Support.

a tight floor, the planks should be laid with a slope to the side of at least 1 inch in 10 feet, and scuppers provided at frequent intervals along the curbs or wheel guards for drainage. It may be necessary to raise the floor at the middle to allow drainage to each side in wide roadways. Tight plank floors are not ordinarily advised. A trestle bridge may be built so that the roadway is a little higher at the center of the bridge than at the ends by varying the height of the bents, thus allowing the use of floor joists and girders of uniform size. A slope of 1 inch in 10 feet will drain the bridge to the ends instead of crosswise.

CHAPTER V.

JOINTS AND METAL DETAILS.

The long members of truss bridges, such as the top and bottom chords, will need to be built up out of medium length timbers in the ordinary case. Where such connections are necessary, the plain fishplate, tabled fishplate, or scarf joint will be of best service. The tabled fishplate joint is the best type of tension joint for use in heavy timber work. Scarf joints are used for small tensile stresses and for compression stresses, also where small reversals of stress are likely to occur.

A plain fishplate joint is shown in Fig. 10, while Figs. 13 and 12 show the tabled fishplate and scarf types. The plates in the plain fishplate or tabled fishplate joints are of timber or steel, and the keys in the scarf joint are of oak or other hard wood. The tables on the steel fishplate joint are made by riveting flat pieces of steel to the main plates in the form of ribs. These take the place of the wood tables shown in Fig. 13.

Methods to be used in the design of fishplate and other bolted types of timber joints, together with tables on the strength of bolts may be found in the American Civil Engineers' Pocket Book, Dewell's Timber Framing, or in Jacoby's Structural Details.

Panel Point Joints The type of joint used at the ends of the lower chord of trusses will vary from an ordinary bevelled end on the slanting strut held to the horizontal chord by a bolt, strap, or combination of the two, up to a joint of the double step type shown in Fig. 12. Care should be taken in designing double step joints to see that the second step extends down into the timber deep enough to provide a large shearing surface for the pressure from that step.

The connections at the hips of the truss are generally some type of miter joint covered by a steel or iron plate to distribute the pressure from the vertical tension rod located there and to hold the two ends of the timbers in place. Examples of these joints will be found in the various bridges shown.

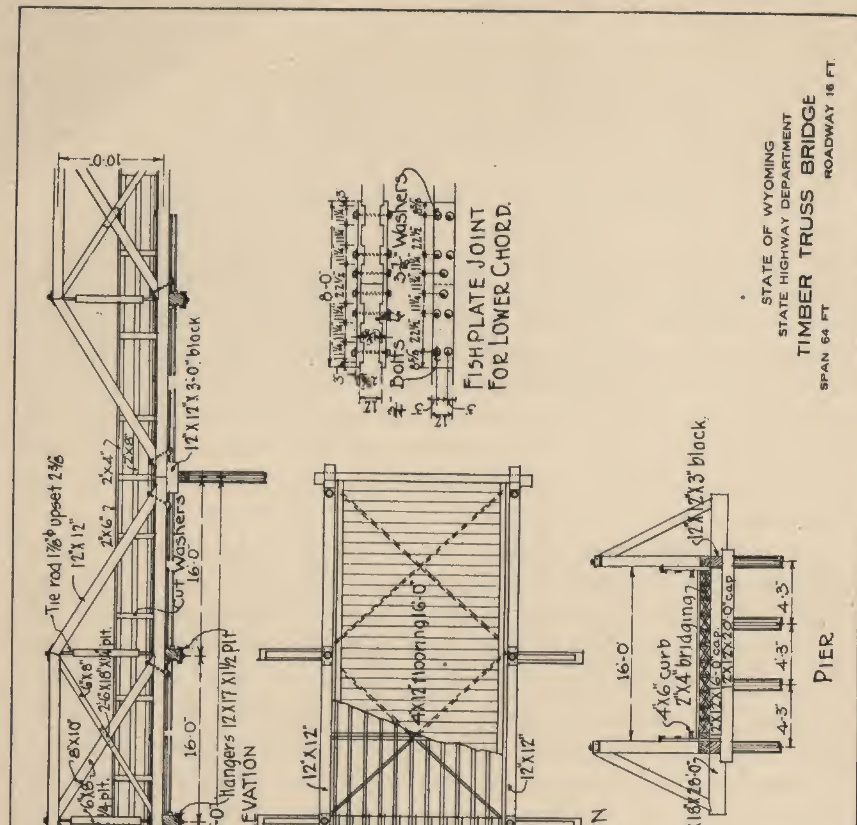


Fig. 13. Floor Bracing and Detail of Joints.

The slanting web members of trusses are held at the panel points by bolts in the small structures, or by single step joints. In larger bridges angle blocks are used, or the struts are bevelled and bolted or strapped to the chords with or without the single step joint.

Angle Blocks Angle blocks which provide the support at the ends of compression members between the upper and lower chords of trusses are made of hardwood, cast iron, or rolled steel shapes. If cast iron blocks are used, the design of their webs and lugs should be such as to transmit the thrust of the braces to the members thus connected. The bearing surface of the lugs which rest in the chords should be large enough to carry the horizontal component of the thrust without exceeding the safe value for end crushing for that particular wood. The necessary bearing area for the base of the block will be limited in a similar manner by the vertical component of the thrust and the allowable crushing strength across the grain of the wood. These areas should be figured on the basis of the area of the member itself without considering the packing blocks. Where a brace and counterbrace meet at a block, it may be necessary to make the area of the base larger than calculated for bearing purposes only.

Short lengths of rolled steel angles have been used as angle blocks, placing the angle over the end of the wood member and notching the upper and lower chords deep enough to obtain the proper bearing area for the horizontal component of the thrust. The bevelled end of the strut covered in part by one leg of the angle provides the proper amount of horizontal bearing area.

Hardwood angle blocks consist of bevelled pieces of timber bolted down over the end of the slanting struts at the lower chord, or bolted up into the angle between struts at the upper chord. Blocks of this type are shown in Figs. 12 and 14. Another type of wood angle block consists of a piece of hardwood with slanting faces perpendicular to the center lines of the struts. These blocks are placed at the joints of the upper and lower chords where the two struts and the tie rod meet. The blocks are dapped into the chords and the tie rods pass through them. Often the struts are held in place on the blocks by dowels.

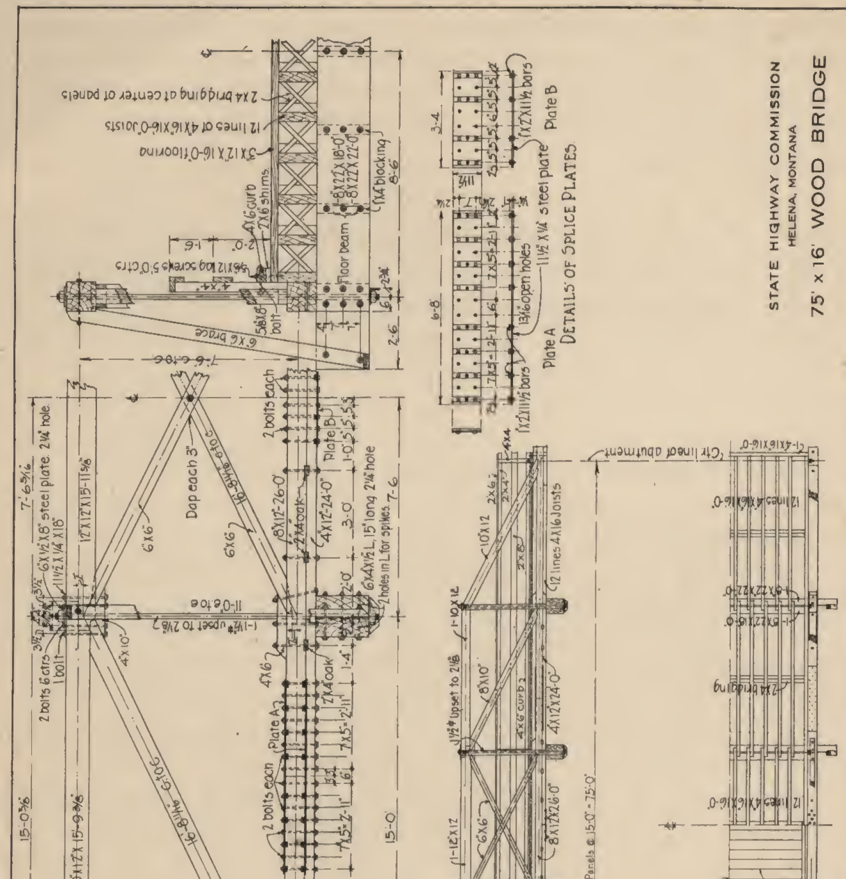


Fig. 14. Use of Angle Blocks and Steel Splice Plates.

Metal Hangers Hangers for holding the floor beams in truss bridges may be of cast iron, flat steel bars bent into the shape of stirrups, or rolled steel structural shapes. Short lengths of steel angles or channels are often used with or without small steel plates to serve as washers or to give additional strength. A typical cast iron hanger is shown in Fig. 4. A steel hanger is shown in Fig. 8.

Trestle Joints Trestle caps are held to the top of the piling or bents by drift bolts driven through the cap and into the support, or by mortise and tenon joints. The use of drift bolts is the simplest and cheapest method of fastening trestle caps in place, but it is difficult to remove them in case of needed repairs. Tapering bolts without heads are preferable since the head on a bolt crushes the wood under it when driven flush with the surface and may cause decay in the wood at these points. Holes slightly smaller than the bolts should be bored in both timbers.

The mortise and tenon joint has a rectangular projection on the end of the timber or pile which is inserted in a hole of similar shape in the cap or timber, and fastened in place by a wooden pin. The tenon is shorter than the depth of the hole or mortise in the cap and the pin is placed about one-third of the length of the tenon from the shoulder, with the hole in the tenon a little nearer the shoulder than the hole in the mortise so that the pin will pull the joint together.

In framed timbers with the mortise placed downward, it is advisable to bore a hole down through the timber at the bottom of the mortise to drain the joint in case water enters around the tenon.

A large amount of valuable detail and information in regard to framing timber bridges may be found in Structural Details, by H. S. Jacoby.

Protection of Joints Decay in timber bridges is most likely to show first at the joints, therefore, these parts should receive the most careful attention in framing. All contact surfaces in joints should join closely with no space for moisture to enter. These surfaces should be painted thoroughly with several coats of hot creosote oil or other recog-

nized preservative, giving each coat a sufficient time to become absorbed before the next coat is applied. If treated timber is used, it should be framed ready for erecting if possible before the preservative treatment is applied. All surfaces cut and all holes bored after treatment should be protected by brush coating. Bolts, washers, or plates should be coated with the same preservative before driving or placing.

If untreated timbers are used, all surfaces of any kind where timber touches timber or metal should be given two thorough brush coats of hot creosote, or similar preservative treatment.

Metal Details Where metal details are required in the construction of timber bridges, the following specifications taken from the 1915 Manual of the American Railway Engineering Association, Report of Committee VII, Wooden Bridges and Trestles, will be of service:

SPECIFICATIONS FOR METAL DETAILS

USED IN WOODEN BRIDGES AND TRESTLES.

Wrought Iron 1. Wrought-iron shall be double-rolled, tough, fibrous and uniform in character. It shall be thoroughly welded in rolling and be free from surface defects. When tested in specimens of standard form or in full-sized pieces of the same length, it shall show an ultimate strength of at least 50,000 lbs. per square inch, an elongation of 18 percent in 8 inches, with fracture wholly fibrous. Specimens shall bend cold, with the fiber, through 135 degrees, without sign of fracture, around a pin the diameter of which is not over twice the thickness of the piece tested. When nicked and bent, the fracture shall show at least 90 percent fibrous.

Steel 2. Steel shall be made by the open-hearth process and shall be of uniform quality. It shall contain not more than 0.05 percent sulphur. If made by the acid process it shall contain not more than 0.06 percent phosphorous; and if made by the basic process not more than 0.04 percent phosphorous. When tested in specimens of standard form, or full-sized pieces of the same length, it shall have a desired ultimate tensile strength of 60,000 lbs. per square inch. If the ultimate strength varies more than 4,000 lbs. from that desired, a retest shall be made on the same gage, which, to be acceptable, shall be within 5,000 lbs. of the desired ultimate. It shall have a minimum percentage of elongation in 8 inches of $\frac{1{,}500{,}000}{\text{ultimate tensile strength}}$; and shall bend cold without fracture 180 degrees flat. The fracture for tensile tests shall be silky.

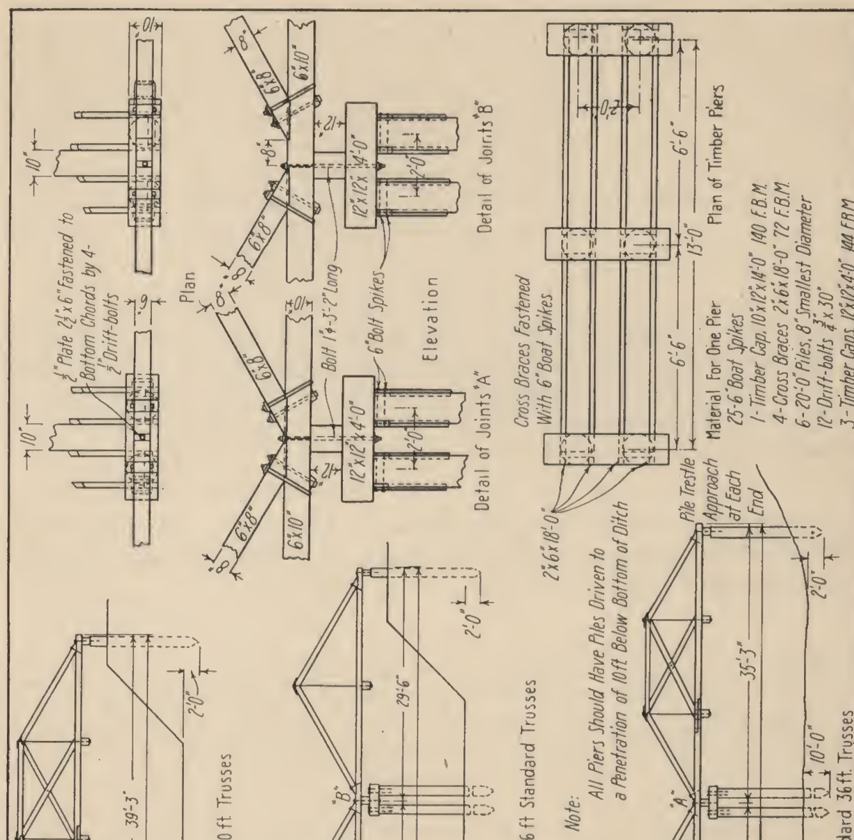


Fig. 15. Detail of Timber Bridge Piers. *(Courtesy Morgan Engineering Company, Memphis.)*

Cast Iron 3. Except where chilled iron is specified, castings shall be made of tough gray iron, with sulphur not over 0.10 percent. They shall be true to pattern, out of wind and free from flaws and excessive shrinkage. If tests are demanded, they shall be made on the "Arbitration Bar" of the American Society for Testing Materials, which is a round bar 1¼ inches in diameter and 15 inches long. The transverse test shall be made on a supported length of 12 inches, with load at middle. The minimum breaking load so applied shall be 2,900 lbs., with a deflection of at least 1/10 inch before rupture.

Bolts 4. Bolts shall be of wrought-iron or steel, made with square heads, standard size, the length of the thread to be 2½ times the diameter of bolt. The nuts shall be made square, standard size, with thread fitting closely the thread of bolt. Threads shall be cut according to U. S. Standards.

Drift Bolts 5. Drift bolts shall be of wrought-iron or steel, with or without square head, pointed or without point, as may be called for on plans.

Spikes 6. Spikes shall be of wrought-iron or steel, square or round, as called for on the plans. Steel wire spikes, when used for spiking planking, shall not be used in lengths more than 6 inches; if greater lengths are required, wrought or steel spikes shall be used.

Packing Spools or Separators 7. Packing spools or separators shall be of cast-iron, made to size and shape called for on plans. The diameter of hole shall be 1/8 inch larger than the diameter of packing bolts.

Cast Washers 8. Cast washers shall be of cast-iron. The diameter shall be not less than 3½ times the diameter of bolt for which it is used, and its thickness equal to the diameter of bolt. The diameter of hole shall be 1/8 inch larger than the diameter of the bolt.

Wrought Washers 9. Wrought washers shall be of wrought-iron or steel, the diameter shall be not less than 3½ times the diameter of bolt for which it is used, and not less than ¼ inch thick. The hole shall be 1/8 inch larger than the diameter of the bolt.

Special Castings 10. Special castings shall be made true to pattern, without wind, free from flaws and excessive shrinkage; size and shape to be as called for by the plans.

CHAPTER VI.

QUALITY OF TIMBER USED.

In order to obtain proper service from timber bridges, it is most essential that a good quality of timber be used. The special requirements for timbers which constitute good quality deal with their strength and lasting power. The strength of any timber will be determined by its weight or density; the size, quality and distribution of knots, and the presence or absence of defects. The density or dry weight of wood of a given species may be regarded as a measure of its strength.

The size, character and distribution of knots may materially affect the strength of any good timber, as indicated in the appendix to the suggested Building Code of the National Board of Fire Underwriters.

"The weakening effect of knots also depends upon their position, as well as their soundness, tightness and the amount they distort the grain of the wood from a straight line. A comparatively small knot near the lower edge of a beam may be more harmful than a large knot located elsewhere. For example, a series of tests made upon loblolly yellow pine beams by the U. S. Forest Service, showed that the average strength of such beams with knots located in the bottom quarter of the middle half of the beams, was reduced 25 percent below that of similar beams with knots located in other portions. In such cases a knot near the neutral plane may act as a pin and serve to strengthen the beam against failure by horizontal shear.

"The number, character and location of defects in timber has much to do with its strength value. Checks and shakes in beams reduce the area which resists horizontal shear. Such defects are most harmful in the middle half of the height of the beam, as they are then comparatively near the neutral plane where their effect is greatest. The best place to judge of the effect of such defects is on the ends of the timber."

It should be noted that most timber specifications have explanatory clauses relating to the size of timbers as specified. The American Society for Testing Materials and the American Railway Engineering Association have adopted a clause which is used more or less universally, according to which rough sawed timbers should not be more than ¼ inch, nor dressed timbers more than ½ inch scant of nominal size; that is, a nominal 12 by 12-inch timber should not be less than 11¾ by 11¾ inches when sawed, or 11½ by 11½ inches when dressed.

(Courtesy American Lumberman.)

Fig. 16. Side View of Glendon Bridge, near Bethlehem, Pa.

The lasting power of timbers will be determined both by the kind and the quality of the wood used and by the conditions which obtain in the structure in which it is employed. The timbers may have sapwood and heartwood in varying percentages. Sapwood is usually short-lived and where conditions are favorable to decay, will usually decay very rapidly. Heartwood, of practically all species, on the other hand, is comparatively long-lived.

Recent studies by Dr. Sanford M. Zeller, published in Volume 5, Annals of the Missouri Botanical Garden, 1918, on the relative lasting power of heart timber of the various species of southern pine, have shown that the heartwood of longleaf and shortleaf pines last equally well provided they have the same density. Also, that there is a definite relation between strength and lasting power of the heartwood.

The wide use of structural timber has led to the framing of standard specifications by national engineering societies such as the American Society for Testing Materials, the American Railway Engineering Association, and the American Wood Preservers' Association. Examples of such specifications are shown by the following sections taken by permission from the Manual of the American Railway Engineering Association

(Courtesy American Lumberman.)

Fig. 17. View through Driveway of Glendon Bridge.

and the copyrighted Standards and Tentative Standards of the American Society for Testing Materials. Other specifications will be found on pages 63 and 66.

STANDARD SPECIFICATIONS FOR SOUTHERN YELLOW PINE BRIDGE AND TRESTLE TIMBERS * †

(To Be Applied to Single Sticks and not to Composite Members)

General Requirements. 1. Except as noted, all timber shall be sound, sawed to standard size, square cornered and straight; close grained and free from defects such as injurious ring shakes and cross grain, unsound or loose knots, knots in groups, decay, or other defects that will materially impair its strength.

Standard Size. 2. "Rough timbers sawed to standard size" means that they shall not be over $\frac{1}{4}''$ scant from the actual size specified. For instance, a $12 \times 12''$ timber shall measure not less than $11\frac{3}{4} \times 11\frac{3}{4}''$. §

* Adopted, Vol. 10, Part 1, 1909, pp. 537, 539-541, 598-603; Vol. 11, 1910, Part 1, pp. 176, 180, 181, 228-230. Proc. Am. Ry. Eng. Assn.

† These specifications are reprinted from the Manual of the American Railway Engineering Association with permission. The terms "Longleaf" and "Shortleaf" have been changed to read "Dense" and "Sound" respectively.

§ In the grading rules of the Southern Pine Association shown on page 57, this rule applies only to No. 1 common timbers.

Standard Dressing. 3. "Standard Dressing" means that not more than ¼″ shall be allowed for dressing each surface. For instance, a 12x12″ timber, after being dressed on four sides, shall measure not less than 11½″x11½″.

Standard Heart Grade, Dense Pine.

Stringers. 4. Stringers shall show not less than 85 per cent heart on the girth anywhere in the length of the piece; provided, however, that if the maximum amount of sap is shown on either narrow face of the stringer, the average depth of sap shall not exceed one-half inch. Knots greater than 1½″ in diameter will not be permitted at any section within 4″ of the edge of the piece, but knots shall in no case exceed 4″ in their largest diameter.

Caps and Sills. 5. Caps and sills shall show not less than 85 per cent heart on each of the four sides, measured across the sides anywhere in the length of the piece, and shall be free from knots over 2½″ in diameter.

Posts. 6. Posts shall show not less than 75 per cent heart on each of the four sides, measured across the sides anywhere in the length of the piece, and *shall* be free from knots over 2½″ in diameter.

Longitudinal Struts and Girts. 7. Longitudinal Struts and Girts shall be square cornered and sound. One side shall show all heart; the other side shall show not less than 85 per cent heart, measured across the side anywhere in the length of the piece, and shall be free from any large knots or other defects that will materially injure their strength.

Longitudinal X Braces, Sash and Sway Braces. 8. Longitudinal X Braces, Sash Braces and Sway Braces shall be square cornered and sound; shall show not less than 80 per cent heart on each of the two sides, and shall be free from any large knots or other defects that will materially injure their strength.

Ties and Guard Rails. 9. Ties and Guard Rails shall show one side all heart; the other side and two edges shall show not less than 75 per cent heart, measured across the surface anywhere in the length of the piece; shall be free from any large knots or other defects that will materially injure their strength; and where surfaced the remaining rough face shall show all heart.

Standard Grade, Dense and Sound Yellow Pine.

Stringers. 10. Stringers shall be square cornered, with the exception of 1″ wane on one corner or ½″ wane on two corners. Knots shall not exceed in their largest diameter one-fourth of the width of the surface of the stick in which they occur, and shall in no case exceed 4 inches. Ring shakes shall not extend over one-eighth of the length of the piece.

Caps and Sills. 11. Caps and Sills shall be square cornered, with the exception of 1″ wane on one corner, or ½″ wane on two corners. Knots shall not exceed in their largest diameter ¼ of the width of the surface of the stick in which they occur, and in no case shall exceed 4″. Ring shakes shall not extend over one-eighth of the length of the piece.

Posts. 12. Posts shall be square cornered, with the exception of 1″ wane on one corner, or ½″ wane on two corners. Knots shall not exceed, in their largest diameter, one-fourth of the width of the surface of the stick in which they occur, and shall in no case exceed 4″. Ring shakes shall not extend over one-eighth of the length of the piece.

DEFINITION FOR SOUTHERN YELLOW PINE.

(Authorized reprint from the copyrighted Standards of The American Society for Testing Materials, Philadelphia, Pa.)

Southern Yellow Pine. This term includes the species of yellow pine growing in the Southern States from Virginia to Texas, that is, the pines hitherto known as long leaf pine (Pinus palustris), short leaf pine (Pinus echinata), loblolly pine (Pinus taeda), Cuban pine (Pinus heterophylla) and pond pine (Pinus serotina).

Under this heading two classes of timber are designated: (a) dense Southern yellow pine and (b) sound Southern yellow pine. It is understood that these two terms are descriptive of quality rather than of botanical species.

Dense Southern Yellow Pine. (a) Dense Southern Yellow Pine shall show on either end an average of at least six annual rings per inch and at least one-third summer wood, or else the greater number of the rings shall show at least one-third summer wood, all as measured over the third, fourth, and fifth inches of a radial line from the pith. Wide-ringed material excluded by this rule will be acceptable, provided that the amount of summer wood as above measured shall be at least one-half.

The contrast in color between summer wood and spring wood shall be sharp and the summer wood shall be dark in color, except in pieces having considerably above the minimum requirement for summer wood.

In cases where timbers do not contain the pith, and it is impossible to locate it with any degree of accuracy, the same inspection shall be made over 3″ on an approximate radial line beginning at the edge nearest the pith in timbers over 3″ in thickness and on the second inch (on the piece) nearest to the pith in timbers 3″ or less in thickness.

In dimension material containing the pith but not a 5″ radial line, which is less than 2x8″ in section or less than 8″ in width, that does not show over 16 sq. in. on the cross-section, the inspection shall apply to the second inch from the pith. In larger material that does not show a 5″

radial line the inspection shall apply to the three inches farthest from the pith.

The radial line chosen shall be representative. In case of disagreement between purchaser and seller the average summer wood and number of rings shall be the average of the two radial lines chosen.

Sound Southern Yellow Pine. (b) Sound Southern Yellow Pine shall include pieces of Southern pine without any ring or summer wood requirement.

The following general timber specifications and grading rules for southern pine timbers have been approved and adopted by the Southern Pine Association, and are quoted from their publication "Southern Yellow Pine Timbers, Including Definition of the Density Rule," published January 1, 1917.

GENERAL TIMBER SPECIFICATIONS.

Southern Yellow Pine Timbers are graded in accordance with the several rules herein described. The defects enumerated and admitted in the various grades are described as follows:

Knots.

(Adopted by the American Society for Testing Materials, August 21, 1915.)

1. Knots shall be classified as round and spike in form and for quality as sound, encased, loose and unsound; knots are also classed as to size.

Sound Knot. 2. A sound knot is one which is solid across its face and which is as hard as the wood surrounding it; it may be either red or black, and is so fixed by growth or position that it will retain its place in the piece.

Loose Knot. 3. A loose knot is one not firmly held in place by growth or position.

Pith Knot. 4. A pith knot is a sound knot with a pith hole not more than ¼ inch in diameter.

Encased Knot. 5. An encased knot is one whose growth rings are not intergrown and homogeneous with the growth rings of the piece it is in. The encasement may be partial or complete; if intergrown partially or so fixed by growth or position that it will retain its place in the piece, it shall be considered a sound knot; if completely intergrown on one face, it is a watertight knot.

Unsound Knot. 6. An unsound knot is one not as hard as the wood it is in.

Pin Knot. 7. A pin knot is a sound knot not over ½-inch in diameter.

Standard Knot. 8. A standard knot is a sound knot not over 1½ inches in diameter.

Large Knot. 9. A large knot is a sound knot, more than 1½ inches in diameter.

Round Knot. 10. A round knot is one which is oval or circular in form.

Spike Knot. 11. A spike knot is one sawn in a lengthwise direction; the mean or average width shall be considered in measuring these knots.

Wane.

12. Wane is bark, or the lack of wood from any cause, on edges of timbers.

Shakes.

13. Shakes are splits or checks in timbers which usually cause a separation of the wood between annual rings.

Ring Shake. 14. An opening between the annual rings.

Through Shake. 15. A shake which extends between two faces of a timber.

16. Shakes not here-in-before described unless known to have extensive penetration shall not be considered a defect under this classification.

Sizes.

17. All rough timber, except No. 1 Common, must be full size when green. One-quarter inch shall be allowed for each side surfaced.

Lengths.

18. Standard lengths are multiples of two feet, eight to twenty feet, inclusive; extra lengths are multiples of two feet, twenty-two feet and longer. When lineal average is specified, standard of lengths shall be multiples of one foot.

GRADES OF SOUTHERN PINE TIMBERS.

Heart Timbers. 19. All timber specifications, except "Merchantable" and "Select Structural Timbers" specifying heart requirements, shall be considered as a special contract, and shall specify whether the heart requirements refer to surface or girth measurements in each piece.

No. 1 Common Timbers. 20. May be either Dense or Sound Pine.

21. Unless otherwise specified, this grade will admit any amount of sapwood.

22. Common Timbers, rough, 4x4 and larger, may be ¼″ scant in either or both of its dimensions, shall be well manufactured and may have 1½″ wane on one corner one-third the length of the piece, or its equivalent on two or more corners, the wane measured on its face.

23. Timbers 10x10 in size may have 2″ wane as above; the larger sizes may have wane as above in proportion to sizes.

24. Common Timbers may contain sound knots and pith knots, provided that the diameter of any one knot shall not exceed the following in size:

2″	in 4x 4 to 6x 6;	3½″	in 12x12 to 12x14;
2½″	in 6x 8 to 8x10;	4″	in 14x14 to 14x16;
3″	in 10x10 to 10x12;	4½″	in 16x16 to 16x18.

In sizes not mentioned the diameter of knots admissible will increase or decrease in proportion to the size of the timbers on same basis as above specified.

25. In determining the size of knots, mean or average diameter shall be taken, or the equivalent of the above in grouped knots at any one point.

26. Will admit shakes extending one-sixth the length of the piece, round or ring shakes, unsound knots 1½ inch or less in diameter, a limited number of pin worm holes, well scattered, sap stain and seasoning checks. Unless otherwise specified, this grade will admit any amount of sap stain.

Square Edge and Sound Timbers. 27. May be either Dense or Sound Pine.

28. Unless otherwise specified, this grade will admit any amount of sapwood.

29. Square Edge and Sound Timbers shall be well manufactured and shall be free from defects such as injurious ring or round shakes and through shakes that extend to the surface, unsound and loose knots and knots in groups that will materially impair the strength, and shall be free from wane. Seasoning checks and sap stain shall not be considered defects.

Merchantable Timbers. 30. May be either Dense or Sound Pine.

31. All Merchantable Timbers shall be well manufactured and shall be free from defects such as injurious ring and round shakes and through shakes that extend to the surface, unsound and loose knots, and knots in groups that will materially impair the strength. Seasoning checks and sap stain shall not be considered defects.

32. Sizes under 9″ on the largest dimension, shall show two-thirds or more heart surface on one of the wide faces; sizes 9″ and over on the largest dimension shall show two-thirds or more heart on both of the wide faces. When sticks are square the face showing the most heart shall govern the inspection on sizes under 9″ and the two faces showing the most heart

shall govern the inspection when 9″ and over. Heart showing the full length, even if not two-thirds of the area as above, shall meet the requirements of this quality.

33. Wane not exceeding one-eighth of the dimension of the face and one-quarter of the length of the piece on one corner, or the equivalent on two or more corners on not to exceed ten per cent of the pieces, shall be admitted.

Select Structural Material.

(A rule incorporating suggestions by the United States Forest Service.)

Requirements for Density and Rate of Growth.

34. Shall contain only sound wood and be well manufactured.

Shall conform to the definition of Dense Southern Pine as adopted by the American Society for Testing Materials, August 21st, 1915, shown on page 55.

35. Unless otherwise specified, Select Structural Material shall show 85 per cent of heart, girth measurement, measured anywhere in the length of the piece. Any greater or less requirement as to heart shall be expressed in terms of per cent of girth measurement. Sap stain is not a defect in this grade.

36. For the purpose of determining whether any given piece meets the requirements for density and rate of growth, the following rule, suggested by the United States Forest Service, shall be applied. It will be sufficient if either end passes the inspection.

(1) Pith Present or Accurately Located.

(A) Radial line of 5″ present.

(a) Apply inspection over third, fourth and fifth inches.

(B) Radial line of 5″ not present.

(a) Apply inspection to the second inch on 2x3, 2x4, 2x6, 3x3, 3x4, 4x4, or any other dimension material that has less than 16 square inches on the cross section.

(b) In the larger material apply inspection to the 3 inches farthest from the pith.

(2) Pith Not Present or Cannot Be Accurately Located.

(A) Material over 3″ thick apply inspection to three inches nearest the pith.

(B) Dimension material 3″ or less in thickness apply inspection to second inch of the piece nearest the pith.

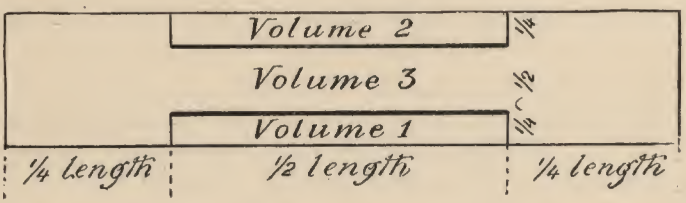
(3) The Radial Line Chosen Shall Show a Representative Number of Annual Rings of Growth and Per Cent of Summer Wood.

Restrictions on Knots in Beams.

37. Shall not have in Volume 1 sound knots greater in diameter than one-fourth the width of the face on which they appear—maximum knot $1\frac{1}{2}''$. Shall not have in Volume 2 sound knots greater in diameter than one-half the width of the face on which they appear—maximum knot $3''$.

38. The aggregate diameter of all knots within the center half of the length of any face shall not exceed the width of that face.

39. The diameter of a knot on the narrow or horizontal face of a beam is to be taken as its projection on a line perpendicular to the edge of the timber. On the wide or vertical face, the smallest dimension of a knot is to be taken as its diameter.



Restrictions on Knots in Columns.

40. Shall not have sound knots greater in diameter than one-third the least width of the column—maximum knots 4 inches.

Restrictions on Shakes and Checks in Beams.

41. Round or ring shakes shall not occupy, at either end of a timber, more than one-fourth the width of green material, nor more than one-third the width of seasoned material.

42. Any combination of checks and shakes which would reduce the strength to a greater extent than the allowable round-shakes will not be permitted. Shakes shall not show on the faces of either green or seasoned timber.

Restrictions on Cross Grain in Beams.

43. Shall not have diagonal grain with slope greater than one in twenty in Volume 1.

CHAPTER VII.

PRESERVATION OF BRIDGE TIMBERS.

We have referred to the advisability of using timber in bridges that has been treated with a recognized preservative, and to the need of protecting joints and contact surfaces where moisture may collect; also, to the liability of decay in piling near the earth or water line. The danger of early decay can be entirely eliminated, and the length of life of sound timbers and piling extended to a period of twenty-five to thirty years, and in many cases still longer, by the use of a good preservative properly applied.

To get such results, only perfectly sound timbers should be treated, and the best results will be obtained generally when the wood is properly seasoned, although some processes permit the treatment of green material. All the outer and inner bark should be removed from piling before treatment. Steaming or boiling of both timbers and piling should be undertaken only in cases of emergency.

Piling, mud sills, caps, guard rails, floor beams, stringers, floor planks, and all parts of the structure in contact with the soil and air or located in such a manner that moisture may collect between contact surfaces should be of treated timber if durability is desired. The first cost will be higher than for untreated material, but the length of service will make the treated material cheaper in the end. Structural timbers consisting largely of sapwood are just as strong as those of heartwood and are treated with greater ease, but they are not durable without preservative treatment. Such protection allows the use of cheaper timbers which could not be used otherwise.

Preservatives and Processes

Coal-tar creosote is the material most commonly used in the preservation of piling and structural timbers. The most effective method of applying creosote preservative is by some form of pressure process. Where the timber is to be exposed to severe weather conditions or liability to decay, a full-cell process treatment should be used, injecting from 10 to 20 pounds

Fig. 18. A Substantial Type of Timber Culvert.

of creosote per cubic foot of material. For less severe cases, or in structures subjected to great mechanical wear, an empty-cell treatment leaving at least 5 pounds of creosote per cubic foot will be sufficient. The empty-cell treatment is especially suitable for structures where the wear will naturally reduce the service of the timber, and the full-cell treatment should be used wherever very long length of life is possible.

Non-pressure processes consist of the open tank and brush treatments using refined coal-tar creosote oil. Open tank treatments with creosote either by the dipping process or the hot and cold bath are frequently used for timbers where it is not desirable or necessary to use one of the pressure treatments.

A condensed description of the various processes for applying creosote oil will be found in the 1917 Proceedings of the American Wood Preservers' Association, giving principal uses and quantities of preservative needed.

Structural Timber

The kind of timber to be selected for treatment is well stated in the following abstract from the Report of Committee on Specifications for the Purchase and Preservation of Treatable Timber, American Wood Preservers' Association, 1917:

"The fundamental requirements of structural timbers for treatment are strength and capacity for treatment to an extent which will insure protection against decay on all exposed surfaces. A penetration of ½ in. on the heart faces may be recommended as a safe minimum on structures above ground, although with a few resistant woods as good a treatment as can be expected will show less than 1/2 in. penetration in the heart.

"The strength requirement is determined by the species, and is further dependent upon the soundness, density of the wood, frequency, size and location of the knots, the extent, character and location of shakes and checks, and the character of the grain. Treatability in most woods is determined by the proportion and relation of heartwood and sapwood, with exceptions in the case of heartwood which takes treatment. Where strength is required, not only the defects which might reduce the strength but also the quality as determined by density should be specified; but where strength is not an essential only the soundness of the timber and the sapwood requirements as determining penetrability need be considered.

"Since sapwood of like density and moisture content to heartwood is also of like strength, the relative proportion of sap and heart on the same species may be considered from this standpoint."

This Committee also divided timbers into five classes in the order of their suitability for treatment based upon sapwood restrictions:

1. "Timber showing no heart on any face.
2. Timbers showing no sap on any face.
3. Heart face timbers with not less than 80 per cent heartwood.
4. Heart face timbers with not over 20 per cent heartwood.
5. Other timbers not falling in any of the foregoing classes."

The American Society for Testing Materials has issued the following tentative specifications for southern pine timber to be creosoted:

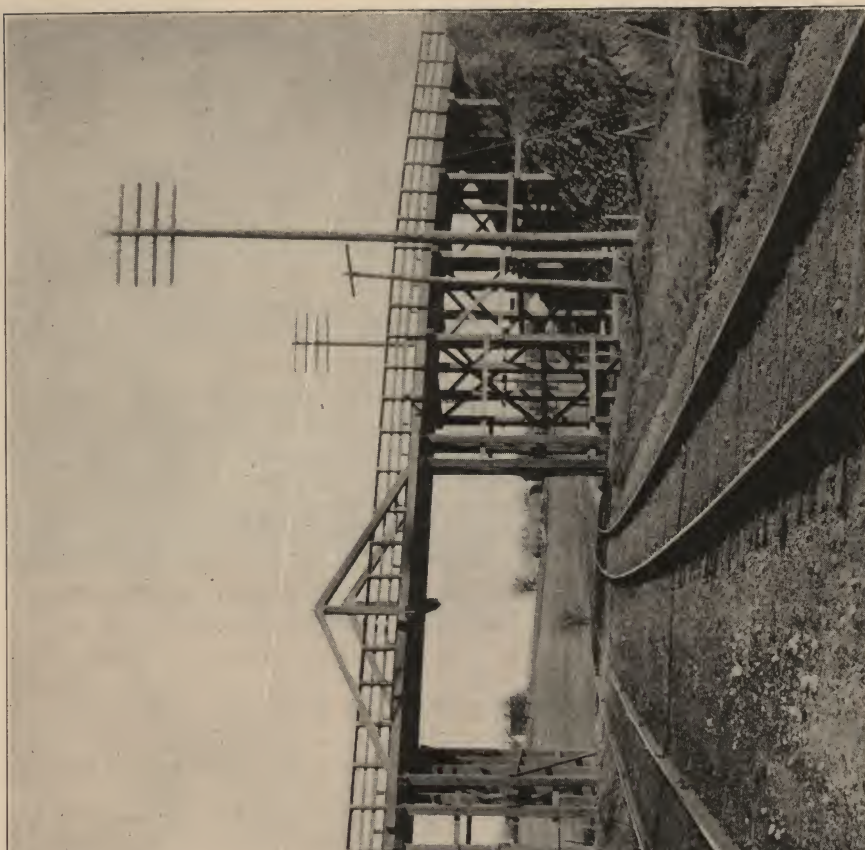
TENTATIVE SPECIFICATIONS
FOR
SOUTHERN YELLOW PINE TIMBER TO BE CREOSOTED.*

Serial Designation: D 24 - 15 T.

The specifications for this material are issued under the fixed designation D 24; the final number indicates the year of original issue, or in the case of revision, the year of last revision.

ISSUED, 1915

*Reprinted from Proceedings of the American Society for Testing Materials, Vol. XVII, Part I, p. 708 (1917).



(*Courtesy Bridge Engineer, Iowa State Highway Commission.*)

Fig. 19. Bridge on the Hawkeye Highway, Dubuque County, Iowa.

General Requirements.

1. The specifications as to strength shall agree with the requirements that will be finally adopted by the Society under the Standard Definitions of Terms Relating to Structural Timber, that is, number of rings per inch or some substitute therefor.

(Included in this section will also be a list of the allowable defects, etc.)

Sapwood. 2. All pieces shall show at least 30 percent sapwood in cross-section. This is based on a minimum treatment of 12 lbs. of creosote per cubic foot of timber.

Bridge Stringers. 3. In bridge stringers knots greater than 1½ in. in diameter shall be at least 4 in. from the edges of the stick. There shall be no knots more than 4 in. in greatest diameter in any part of the stick.

Caps and Sills. 4. Caps, sills, posts and sawed poles shall be free from knots more than 2½ in. in diameter.

Bracing. 5. Longitudinal bracing, cross-arms and similar pieces having small cross-section shall have no knots more than 1 in. in diameter.

Track Ties. 6. Track ties shall show at least 20 per cent sapwood in cross-section. This is based on a minimum full-cell treatment of 8 lbs. of creosote per cubic foot of timber.

Wood Piling Decay in wood piling occurs at the soil line or the water line, while parts of piles which are buried in earth, immersed in water, or are in the air at all times will remain solid for many years. The ideal treatment for piling would affect only those parts which are exposed to decay, but the amount and penetration of preservative needed in piling makes some form of pressure treatment necessary and the whole pile is included. Brush treatments are of but little service in such locations and should only be counted upon for temporary protection. For piling in earth or fresh water where decay is the principle source of failure, either a full-cell process with a treatment of from 10 to 20 pounds of creosote per cubic foot, or an empty-cell process leaving an average of 5 pounds of creosote per cubic foot in the treatable portions of the wood is generally advised. All of the sapwood and as much of the heartwood as possible should be impregnated.

The following tentative specifications for southern pine piles to be creosoted are issued by the American Society for Testing Materials:

TENTATIVE SPECIFICATIONS

FOR

SOUTHERN YELLOW PINE PILES AND POLES TO BE CREOSOTED.*

Serial Designation: D 25 - 15 T.

The specifications for this material are issued under the fixed designation D 25; the final number indicates the year of original issue, or in the case of revision, the year of last revision.

ISSUED, 1915.

General Requirements.

1. The specifications as to strength shall agree with the requirements that will be finally adopted by the Society under the Standard Definitions of Terms Relating to Structural Timber, that is, number of rings per inch or some substitute therefor.

(Included in this section will also be a list of the allowable defects, etc.)

Sapwood. 2. All piles or telegraph poles shall show 40 percent sapwood in cross-section, or there shall be a ring of sapwood not less than 1 in. in thickness all around the heart wood.

Quality. 3. (a) Piles and poles shall be cut from sound live trees, of straight grain and regular taper; without crooks exceeding one-fourth the diameter of the stick at middle of crook when peeled. They shall be free from rot, red heart, holes or rotten knots, shakes and felling checks.

(b) All piles and poles shall have the bark and inner skin carefully removed when the tree is felled; all limbs and knots trimmed flush and butts cut square.

Minimum Diameter. 4. The minimum diameter of piles after peeling shall be as follows:

Length	Butts in.	Tops in.
36 ft. and under	14	10
38 ft. and under 50 ft.	14	9
50 ft. and over	15	9

No pile with butt diameter over 18 in., nor top diameter over 13½ in., will be accepted. The length of each pile is to be legibly marked on the butt with white or black paint.

*Reprinted from Proceedings of the American Society for Testing Materials, Vol. XVII, Part I, p. 710 (1917).

Bridge Painting Untreated timber bridge members which are exposed to decay from weather conditions only may be protected by using a good grade of lead and oil paint on all exposed surfaces. A priming coat and two finish coats are specified for the best results.

The following specifications for painting wooden structures appeared in the September 5, 1917 number of Engineering and Contracting:

"The new standard road specifications of the State Highway Department of Ohio call for the application of three coats of paint to wooden structures unless otherwise ordered. For a ready mixed paint the standard "O" white paint is specified. This consists of

4 gal. raw linseed oil.
1 qt. drier.
75 lb. white lead in oil.
25 lb. zinc oxide in oil.

"Unless otherwise ordered the final coat on all woods where ready mixed paint is used consists of the above. The first and intermediate coats in this case are:

Yellow pine, cypress and similar woods. Coats		Poplar, oak, white pine and similar woods. Coats		
1st.	2nd.	1st.	2nd.	
7	7	7	7	gal. "O" white paint.
0	1/2	2	1/2	gal. raw linseed oil.
1 1/2	0	0	0	gal. benzole.
1	1/2	1/2	1/2	gal. turpentine.

"Where the paint is mixed on the job the different coats for the various woods consist of ingredients proportioned as follows:

Yellow pine, cypress and similar woods. Coats			Poplar, oak, white pine and similar woods. Coats			
1st.	2nd.	Final.	1st.	2nd.	Final.	
3 1/2	4	4	5	4	4	gal. raw linseed oil.
1 1/2	0	0	0	0	0	gal. benzole.
1	1	1	1	1	1	qt. drier.
1	1/2	0*	1	1/2	0	gal. turpentine.
100	100	75	100	100	75	lbs. white lead in oil.
0	0	25	0	0	25	lbs. zinc oxide in oil."

* Or little.

The following extracts are taken from a list of Specifications for Paints published by the Equipment Division, Ordnance Department, U. S. Army. These specifications were prepared in consultation with Paint Committee, National Research Council, Council of National Defense.

White Lead in Oil. It shall be stated whether the basic carbonate or basic sulphate is desired.

White Lead, Basic Carbonate. The dry pigment must be of the best quality, amorphous in structure, and of great opacity. Unless otherwise

(Courtesy Bridge Engineer, Iowa State Highway Commission.)

Fig. 20. Bracing of Supports under Bridge on the Hawkeye Highway.

specified, this basic carbonate white lead must be delivered in paste form, finely ground in pure, clear, raw or refined linseed oil in the proportion of 92 pounds of pigment to 8 pounds of oil. The dry pigment must not contain more than 0.5 per cent moisture.

It must have satisfactory properties, including working under the brush, whiteness, fineness, body, and covering qualities, all of which will be determined by practical tests.

White Lead, Basic Sulphate. The dry pigment must be of the best quality, amorphous in structure, and of great opacity. Unless otherwise specified, this basic sulphate-white lead must be delivered in paste form, finely ground in pure, clear, raw or refined linseed oil, in the proportion of 90 pounds of pigment to 10 pounds of oil. The dry pigment must not contain more than 0.5 per cent moisture, not more than 8.5 per cent zinc oxide (ZnO), not more than .075 per cent sulphur dioxide (SO_2) and not less than 12 per cent of lead oxide (PbO).

It must have satisfactory properties including working under the brush, whiteness, fineness, body, and covering qualities, all of which will be determined by practical tests.

Leaded Zinc. The dry pigment shall be pure leaded zinc free from all adulterants, containing not more than 40 per cent basic lead sulphate, the remainder zinc oxide. Moisture shall not exceed 0.5 per cent. Water soluble salts shall not exceed 1.5 per cent. Sulphur dioxide shall not exceed 0.75 per cent.

The pigment, when required ground to a paste in oil, shall be of the same quality as the dry pigment, and shall be ground in at least 12 per cent by weight of pure bleached, refined linseed oil.

Putty. Must be of the best quality and made from whiting and pure raw linseed oil only. It shall contain 85 per cent whiting and 15 per cent linseed oil. It must be practically free from grit or alkali, and must not contain more than 1 per cent of water.

Raw or Refined Linseed Oil. Must be absolutely pure, well-settled oil of best quality. Must be perfectly clear at a temperature of 60° F., and not show a loss of over 2 per cent when heated to 212° F., or show any deposit of "foots" after being heated to this temperature. It shall conform to the following requirements:

	Maximum	Minimum
Specific gravity at 15.5° / 15.5°C	0.936	0.932
Or specific gravity at 25° / 25°C	0.931	0.927
Acid number	6.	.....
Saponification number	195.	189.
Unsaponifiable matter, per cent	1.50	......
Refractive index at 25°C	1.4805	1.4790
Iodine number (Hanus)	......	170.

Boiled Linseed Oil. Must be absolutely pure, well-settled linseed oil boiled with oxides of manganese and lead. It shall conform to the following requirements:

	Maximum	Minimum
Specific gravity at 15.5° / 15.5°C.	0.945	0.937
Acid number	8.	......
Saponification number	195.	189.
Unsaponifiable matter, per cent	1.5	......
Refractive index at 25°C	1.484	1.479
Iodine number (Hanus)	......	168.
Ash, per cent	0.7	0.2
Manganese, per cent	....	0.03
Lead, per cent	......	0.1

Turpentine. These specifications apply both to the turpentine that is distilled from pine oleoresins, and commonly known as gum turpentine or spirits turpentine, and to the turpentine commonly known as wood turpentine that is obtained from resinous wood, whether by extraction with volatile solvents, by steam, or by destructive distillation. The bidder should state whether gum spirits or wood turpentine is furnished.

The turpentine must be clear and free from suspended matter and water. The color shall be water white. The specific gravity shall not be less than 0.860 or more than 0.875 at 15.5°C. The refractive index shall be not less than 1.468 or more than 1.478 at 15.5°C. The initial boiling point shall be not less than 150°C nor more than 160°C. Ninety per cent of the turpentine shall distill below 170°C. The polymerization residue shall not exceed 2 per cent and its refractive index at 15.5°C shall not be less than 1.500.

Mineral Spirits. This shall be hydrocarbon distillate, water white, neutral, clear and free from water. It shall have no darkening effect when mixed with basic carbonate white lead.

When 100 cc. are submitted to continuous distillation in an Engler flask with a condenser 22 inches long at an angle of 30° with the horizontal, and cooled with water, the first drop shall issue from the condenser at a temperature of not less than 265° F. and 97 per cent shall distill below 470° F.

When 10 cc. of the distillate are placed in a glass crystallizing dish 2½ inches in diameter in a steam bath maintained at a temperature of 212° F. and evaporated, not more than 2/10 of 1 per cent of residue shall remain after 2½ hours. The flash point shall be not less than 85° F. when determined by the closed Abel tester method, the test being made in the usual official manner.

Drier. To be composed of lead, manganese, or cobalt, or a mixture of any of these elements, combined with pure linseed oil and thinner. The thinner shall consist of 75 per cent mineral spirits and 25 per cent turpentine. It shall be free from adulterants, sediment, and suspended matter. Resins

or "gums" other than rosin may be used at the option of the manufacturer (but the presence of rosin in any form will be cause for rejection). The drier shall not flash below 35° C. (95° F.) in an open tester. When the drier is thoroughly mixed with linseed oil that will not break under 315° C. (600° F.) in the proportion of 5 volumes of drier to 95 volumes of oil, no curdling shall result within 2 hours after mixing, and the mixture when flowed on a clean glass plate held in a vertical position, shall dry in not more than 18 hours at a temperature between 15° and 35° C.

Creosote as a Paint

Where economy is desirable and conditions permit a uniform dark brown color, refined coal-tar creosote oil is the cheapest and the most lasting paint that can be applied to timber bridges. It is claimed that the cost is less than one-third of that of a first grade standard oil paint, and its lasting quality, due to the fact that it will not evaporate, peel or crack is considerably greater than that of any paint. It is true that the brown color resulting from the use of creosote oil is objectionable in some cases, but in general the effect is pleasing and ordinary discolorations do not show.

CHAPTER VIII.

WOOD CULVERTS.

It is difficult to state the difference between a small bridge and a large culvert, since each may be used for the same purpose and may be constructed along the same general lines. Large culverts may be built similar to the design shown in Fig. 27, while small culverts for ordinary highway drainage are generally of the box type.

Box Culverts Wood box culverts for highway drainage may be used with success if they are substantially built and carefully placed. For permanent service the timber used should be given a thorough preservative treatment with coal-tar creosote oil either by a pressure process or by open

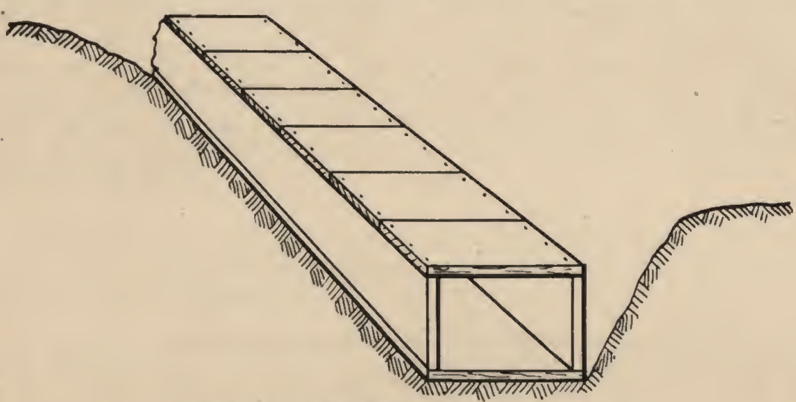


Fig. 21. Small Type of Box Culvert.

tank treatment. This treatment should be applied to the timber after it is cut to length and ready to put in place, so that no freshly cut surfaces will be exposed to decay. It is advisable to leave an absorption of at least five to eight pounds of oil per cubic foot of wood where the timber is to be in contact with the soil, or is exposed to alternate wet and dry conditions. Wood culverts thus treated should be good for twenty to thirty years of service without renewal. Untreated timber should not be used in culverts which are buried unless the purpose is of a temporary nature.

Box culverts may be either of the design shown in Fig. 21 or Fig. 22. The smaller type shown in Fig. 21 is built of plank without a supporting frame-work and is easily made and installed. It is intended for lighter loads and more temporary use than the one shown in Fig. 22. The sides are made of 3 in. by 10 in. or 3 in. by 12 in. planks, while the top and bottom are of 3-inch stock of any width. The limiting width of top for this kind of culvert for country roads should be 20 inches. If

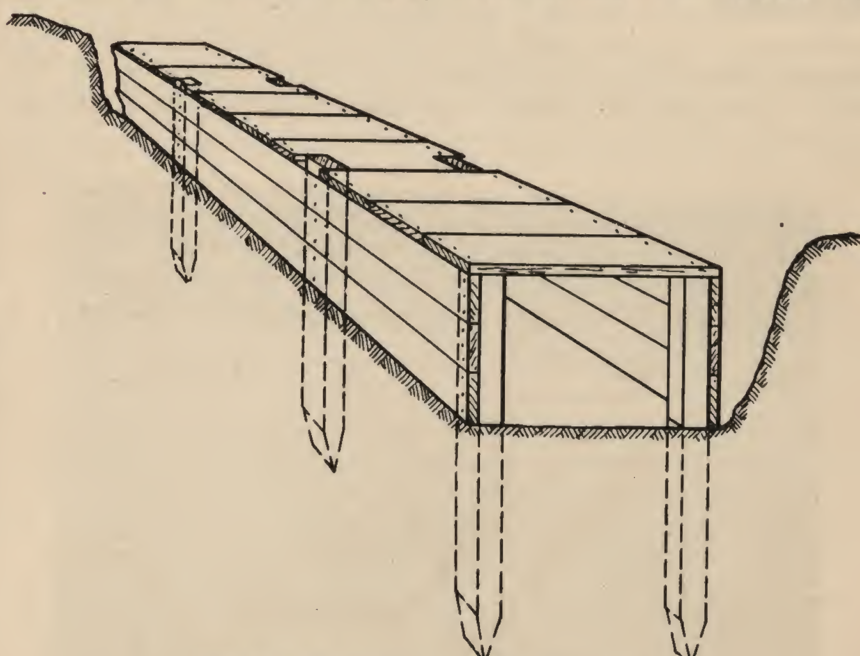


Fig. 22. Box Culvert with Supporting Posts.

4-inch plank is used the total width may be increased to 30 inches.

The type of box culvert shown in Fig. 22 consists of pairs of posts 6 in. by 6 in. or over in size driven to a depth of at least 3 feet below the line of the bottom, and spaced about 4 feet apart across the roadway. Thick plank sides are nailed to these posts, and the top planking is then nailed to the sides as shown. The posts should extend up through the top planking to aid in strengthening the sides against earth pressure. The thickness of the sides and top will depend upon the depth at which the culvert is buried and the amount of load that is likely to come upon it. For heavy traffic on country roads, it is

advisable to use 4-inch stock for the top and sides of box culverts between 20 and 30 inches in total width, and 6-inch stock for all other widths up to 60 inches. The bottom of a culvert of this type should be paved with flat stones if possible to prevent the scouring action of the water passing through it.

Filling and Head Walls

In the use of road culverts of the buried or box type, care should be taken to see that the filling at the sides is carefully tamped into place to prevent water from flowing along the sides of the culvert. Timber end walls or head walls similar to

Fig. 23. End Wall for Box Culvert.

the one shown in Fig. 23 will aid in keeping the water from washing the earth away at the entrance to the culvert, and also add to the appearance of the work. Stock 2 or 3 inches in thickness will be suitable for such walls. An extra pair of posts will be needed at each end of the culvert to support the outer ends of the planks in these end walls. The culverts should be protected on top by a thick earth covering with gradually sloping approaches if necessary.

Large Box Culverts

A type of box culvert for heavy loads, wide spans, and considerable quantities of water may be built by placing 6 in. by 12 in. sills with the 12 inch dimension horizontal about 8 feet apart across the road to support the sides. These sides are made of two pieces of 6 in. by 12 in. stock, one placed on top of the other and fastened together by $\frac{3}{4}$ in. by 20 in. drift bolts 6 feet apart, thus making solid walls 6 inches thick. The top is made of 6 in. by 12 in. stock laid across the sides with every sixth stick 8 inches thick and notched 2 inches so that it fits down between the sides. The bottom of the culvert is made of 2-inch plank laid lengthwise across the sills and fastened to them. This culvert can be used for total widths up to 5 feet with heavy highway loads.

CHAPTER IX.

PLANS OF TIMBER HIGHWAY BRIDGES.

The following pages show types of timber highway bridges mentioned in the preceding chapters. The drawings throughout the bulletin have been made in nearly all cases from standards furnished by state highway engineers, and represent current practice in various parts of the country. The loading used as a basis for calculation has been given in many cases and bills of material shown in some instances. Some of these plans give sizes of members to be used for various lengths of span and widths of roadway.

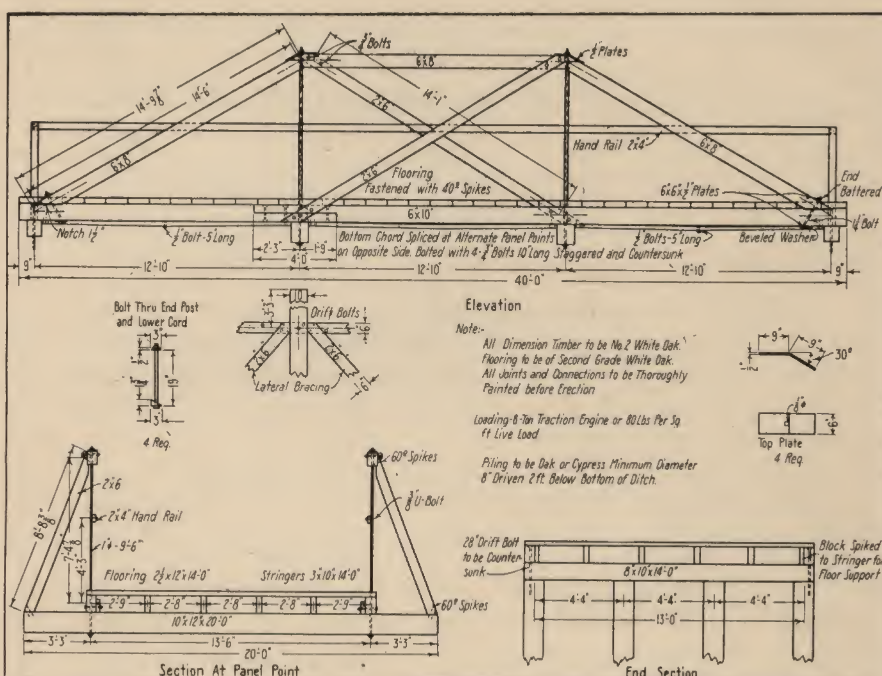
The object in showing these drawings is to give the designer an idea of methods and details of construction followed in different states. It is not claimed that the plans will suit all conditions, and designers are cautioned against snap judgment in using them. Every bridge is an individual problem and should be treated as such. While the designer may believe that one of these bridges meets the requirements of his problem, it will be on the side of safety for him to check all details.

Where sizes of timbers are given it is safe to assume that a good quality of structural material has been specified, and the table of allowable unit stresses given on page 32 may be used to an advantage in connection with the suggestions contained in Chapter VI.

The plans and drawings themselves contain many details of construction not referred to in the text and are of value since they represent the experience of many engineers. Even if no one particular plan which is shown here is followed, the best points in several may be combined in a given case.

Steel members or metal details may be designed or checked by the specifications and proportions shown on page 48.

A convenient method of making up a bill of material for a small bridge is shown on pages 84, 85 and 86. Other types of a more condensed form are shown on pages 82 and 87.



(Courtesy Morgan Engineering Company.)

Fig. 24. Forty-Foot Wood Truss Highway Bridge.

40 Foot Wood Truss
HIGHWAY BRIDGE
Morgan Engineering Company, Memphis, Tenn.
Bill of Material

Material	F.B.M	Total	Material	F.B.M.	Total
Sills—2- 8"x10"x14'0".......	187		Tie Rods—4-1"Φx9'6".......		
2-10"x12"x20'0".......	400		Drift Bolts—4-28"..........		
2- 8"x10"x30'0".......	300		24-6"..........		
2- 6"x10"x16'0".......	160	1047			
Beams— 6-6"x 8"x16'0".....	384		Bolts—3-½"Φx 5"..........		
4-2"x 6"x16'0".....	64		8-¾"Φx10"..........		
4-2"x 6"x10'0".....	40		16-¾"Φx8'..........		
12-3"x10"x14'0".....	420		U Bolts—4-⅜"Φx3½".......		
6-2"x 6"x20'0".....	120	1028	Spikes—45 lbs.............		
Flooring—40-2½"x12"x14'0"..	1400	1400	Top Plates—4.............		
Piling Min. Diam. 8"........			Plates—4-6"x6"x½"		
			4—1¼" Bolts		
Hand Rail—2-2"x4"x40'0"....		54	Washers for All Bolts......		

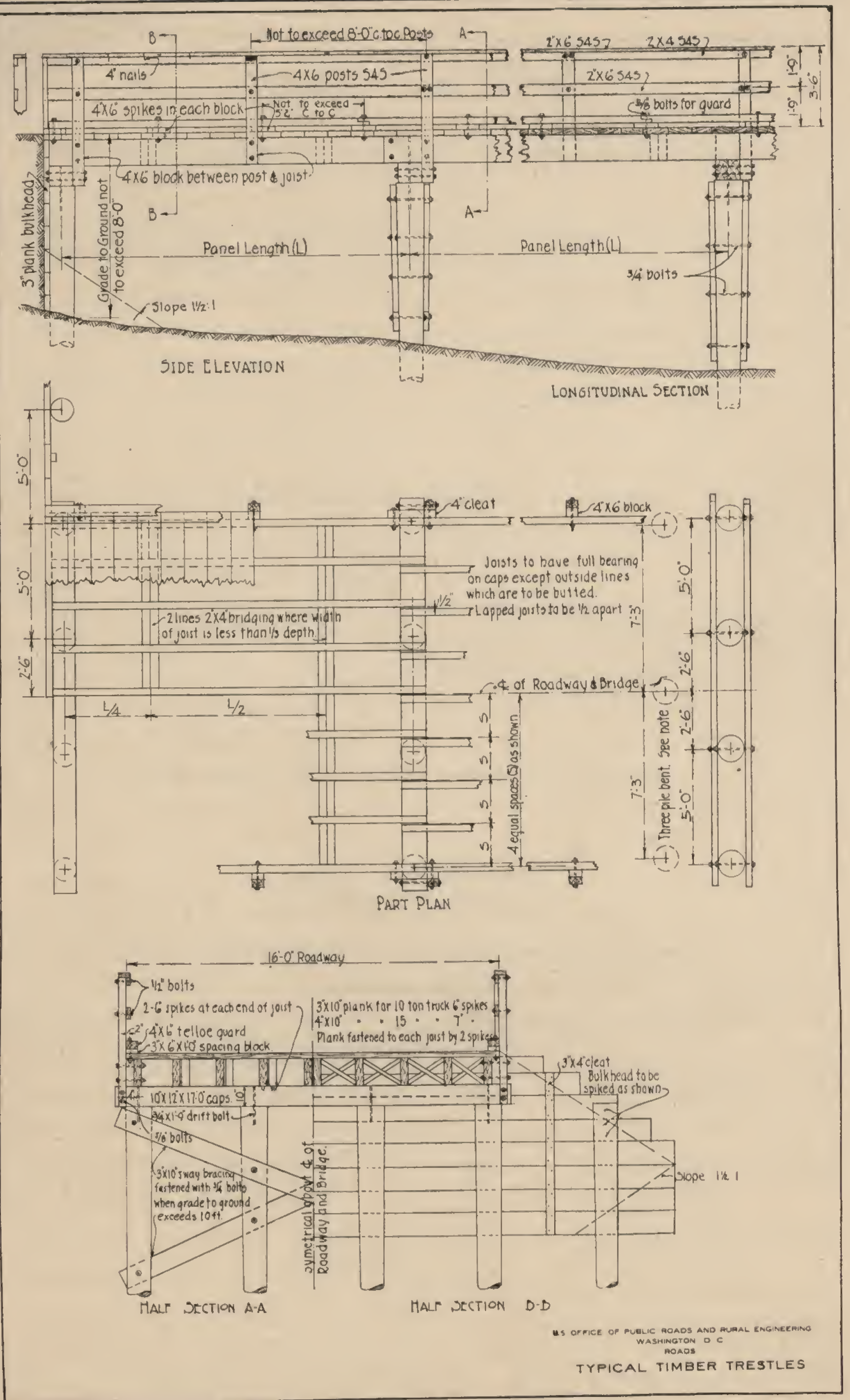


Fig. 25. Details of Timber Trestles.

U. S. Office of Public Roads and Rural Engineering, Washington, D. C.
(ROADS)

TYPICAL TIMBER TRESTLES

Spans 10 to 29 ft. 16 ft. Roadway

Dimensions and Quantities for Superstructure

Capacity 15 Ton Truck

Panel Length (L)	Size of Joists	Intermediate Panel: Joists	Intermediate Panel: Floor Railing Details	Intermediate Panel: Total Lumber	Intermediate Panel: Bolts Washers Spikes Nails
Feet	Inches	Ft. B. M.	Ft. B. M.	Ft. B. M.	Pounds
10	6x12	590	800	1390	80
	4x14	460	840	1300	
11	6x12	650	870	1520	90
	4x14	500	920	1420	
12	6x12	700	940	1640	90
	4x16	620	990	1610	
13	8x12	1010	1020	2030	90
	6x14	880	1020	1900	
	4x16	670	1070	1740	
14	8x12	1080	1090	2170	90
	6x14	950	1090	2040	
	4x16	720	1140	1860	
15	8x12	1150	1170	2320	100
	6x14	1010	1170	2180	
16	10x12	1530	1240	2770	
	6x14	1070	1240	2310	100
	6x16	1230	1240	2470	
17	10x12	1620	1340	2960	120
	8x14	1510	1340	2850	
	6x16	1300	1340	2640	
18	10x12	1710	1410	3120	130
	8x14	1600	1410	3010	
	6x16	1370	1410	2780	
19	10x12	1800	1490	3290	130
	8x14	1680	1490	3170	
	6x16	1440	1490	2930	
20	8x14	1760	1560	3320	130
	8x16	2020	1560	3580	
21	10x14	2310	1640	3950	140
	8x16	2110	1640	3750	
22	10x14	2410	1710	4120	150
	8x16	2210	1710	3920	

Dimensions and Quantities—Substructure

Grade to Ground	Sway Bracing—Intermediate Bent: Sets	Length	Lumber	Bolts
Feet	No. Reqd.	Feet	Ft. B. M.	Pounds
10-12	1	18	90	35
12-15	1	20	100	35
15-18	1	22	110	35
18-23	2	18 & 20	190	60
23-26	2	20	200	60
One Cap 10" x 12" x 17'-0"			170	10

Grade to Ground	Bulkhead—End Bent: Lumber	Spikes
Feet	Ft. B. M.	Pounds
4	270	5
5	360	5
6	460	10
7	550	10
8	640	10

Capacity 10 Ton Truck

Panel Length (L)	Size of Joists	Intermediate Panel: Joists	Intermediate Panel: Floor Railing Details	Intermediate Panel: Total Lumber	Intermediate Panel: Bolts Washers Spikes Nails
Feet	Inches	Ft. B. M.	Ft. B. M.	Ft. B. M.	Pounds
10	4x12	400	640	1040	70
	3x14	350	680	1030	
11	4x12	430	700	1130	80
	3x14	380	740	1120	
12	6x12	700	760	1460	80
	3x14	410	800	1210	
13	6x12	760	810	1570	80
	4x14	590	860	1450	
14	6x12	810	870	1680	90
	4x14	630	910	1540	
	4x16	720	910	1630	
15	6x12	860	930	1790	90
	4x14	670	970	1640	
	4x16	770	970	1740	
16	6x12	920	990	1910	100
	6x14	1070	990	2060	
	4x16	820	1030	1850	
17	6x12	970	1070	2040	110
	6x14	1130	1070	2200	
	4x16	870	1110	1980	
18	8x12	1370	1130	2500	120
	6x14	1200	1130	2330	
	4x16	910	1170	2080	
19	8x12	1440	1180	2620	120
	6x14	1260	1180	2440	
	4x16	960	1220	2180	

Panel Length (L)	Size of Joists	Intermediate Panel: Joists	Intermediate Panel: Floor Railing Details	Intermediate Panel: Total Lumber	Intermediate Panel: Bolts Washers Spikes Nails
Feet	Inches	Ft. B. M.	Ft. B. M.	Ft. B. M.	Pounds
20	8x12	1510	1240	2750	120
	6x14	1320	1240	2560	
	6x16	1510	1240	2750	
21	10x12	1980	1300	3280	130
	6x14	1390	1300	2690	
	6x16	1580	1300	2880	
22	10x12	2070	1360	3430	130
	8x14	1930	1360	3290	
	6x16	1660	1360	3020	
23	10x12	2160	1420	3580	130
	8x14	2020	1420	3440	
	6x16	1730	1420	3150	
24	10x12	2250	1470	3720	130
	8x14	2100	1470	3570	
	6x16	1800	1470	3270	
25	10x14	2730	1560	4290	150
	8x14	2180	1560	3740	
	6x16	1870	1560	3430	
26	10x14	2840	1610	4450	160
	8x16	2600	1610	4210	
27	10x14	2940	1670	4610	160
	8x16	2690	1670	4360	
28	10x14	3050	1730	4780	160
	8x16	2780	1730	4510	
29	10x14	3150	1790	4940	160
	8x16	2880	1790	4670	

Washers to be ogee type cast iron for ⅝″ and ¾″ bolts, and cut wrought iron or steel plate washers for ½″ bolts.

DESIGN DATA AND GENERAL NOTES

One typical 10 or 15-ton truck.

Impact allowance, 30 per cent.

Stress in extreme fiber structural timber, 1,600 lbs. per square inch.

Three-pile bents may be substituted for the 4-pile bents shown, only for the 10-ton truck design for panel lengths not to exceed 20 feet.

All piles to be straight sound trees of durable quality and peeled. Butt to be not less than 14 in. diam. and tip not less than 9 in. diam. for piles less than 30 ft., nor less than 8 in. for piles over 30 ft.

Paint:—Railing, 2 coats of white lead and linseed oil.

Tops of piles and caps, the contact surfaces of joists, and the rear surface of bulkhead, 1 coat of soft coal tar pitch or asphaltic paint.

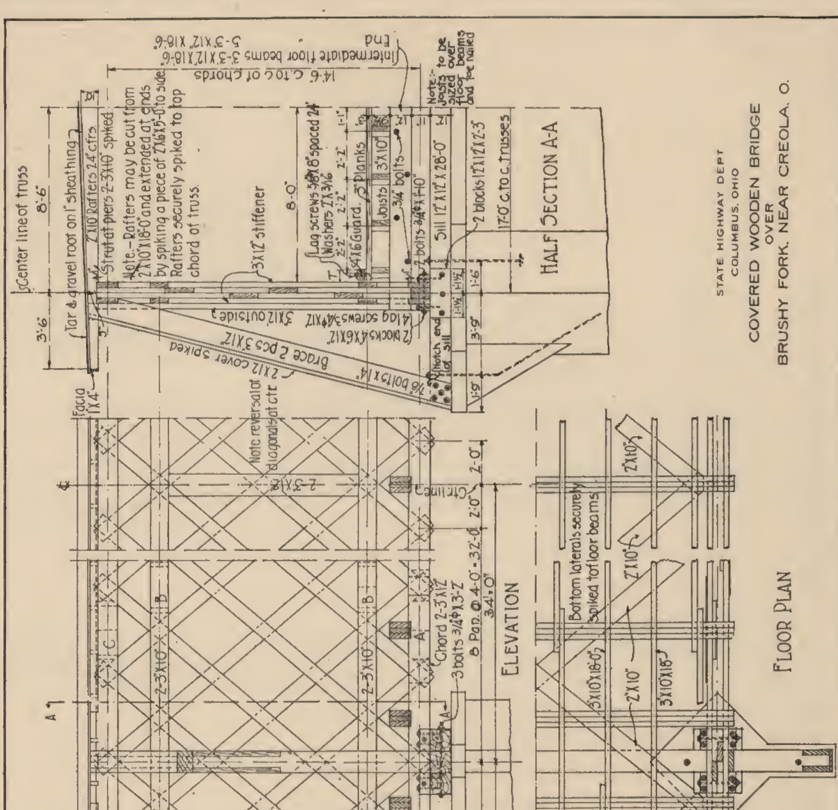


Fig. 26. Detail of Lattice Timber Bridge Shown in Fig. 7.

COVERED WOODEN BRIDGE OVER BRUSHY FORK, NEAR CREOLA, OHIO

Span 68 Ft., Roadway 16 Ft., Loading Class "C" (State Highway Department Specifications)

STATE HIGHWAY DEPARTMENT BUREAU OF BRIDGES, COLUMBUS, OHIO

Bill of Material.

No. Pcs.	Material	Size	Ord. Length	Quantity	Location
48	White Oak	3″x12″	16′0″	2304 ft. B. M.	Chords
6	" "	"	20′0″	360 " " "	"
2	" "	"	8′0″	48 " " "	"
2	" "	"	12′0″	72 " " "	"
44	" "	3″x10″	16′0″	1760 " " "	"
4	" "	"	20′0″	200 " " "	"
4	" "	"	18′0″	180 " " "	"
4	" "	"	14′0″	140 " " "	"
104	" "	3″x 8″	20′0″	4160 " " "	Diagonals
4	" "	"	14′0″	112 " " "	"
3	" "	"	16′0″	96 " " "	" (Cut)
8	" "	3″x10″	12′0″	240 " " "	End Stiffeners (Cut)
4	" "	3″x12″	10′0″	120 " " "	Center "
12	" "	"	16′0″	576 " " "	Stiffeners at Piers
8	" "	"	18′0″	432 " " "	Braces
4	" "	2″x12″	18′0″	144 " " "	"
5	" "	"	16′0″	160 " " "	Splices, Chord (Cut)
4	" "	2″x10″	14′0″	94 " " "	" " "
60	Oak Mixed	"	24′0″	2400 " " "	Rafters
4	" "	3″x10″	20′0″	200 " " "	Top Struts
16	" "	4″x 6″	16′0″	512 " " "	Guard Rail
2	" "	3″x12″	18′0″	108 " " "	End Sills
8	" "	3″x10″	16′0″	320 " " "	End Stringers (Cut)
5	" "	"	10′0″	125 " " "	Int. "
6	" "	"	14′0″	210 " " "	" "
45	" "	3″x10″	18′0″	2025 " " "	" "
85	" "	3″x12″	20′0″	5100 " " "	Floor Beams
2	" "	12″x12″	28′0″	672 " " "	Sills
1	" "	"	18′0″	216 " " "	" (Cut)
4	" "	2″x10″	24′0″	160 " " "	Bottom Laterals
12	" "	"	22′0″	440 " " "	" "
	" "	3″	16′0″	5600 " " "	Flooring
43	" "	2″x6″	16′0″	688 " " "	Nailing Strips

No. Pcs.	Material	Size	Ord. Length	Quantity	Location
2	Oak Mixed	4"x4"	18'0"	48 " " "	Railing
	Shiplap	24.5x120'		3000 " " "	Roof Sheeting
	Poplar or Spruce..........	8'x210'	16'0"	1700 " " "	Siding
	" " "	⅞"x 4"	450'	150 " " "	Trim
	" " "	⅞"x10"	210'	175 " " "	Cap
29½	Squares	Tar & Gravel			Roofing
300	Bolts	¾"	7½" u. h.	Hex. Nut & Head	Diag. Intersections
500	"	"	13½" " "	" " " "	Chords and Ends
50	"	"	17" " "	" " " "	Stiffener at Pier
390	"	"	6½" " "	" " " "	Chord Splices
430	"	⅞"	14" " "	" " " "	Chords
32	"	"	17" " "	" " " "	Chords at Piers
510	"	"	7" " "	" " " "	Chord Splices
8	"	¾"	22" " "	" " " "	Anchors
12	"	"	38" " "	" " " "	"
28	"	⅞"	14" " "	" " " "	Wind Braces
250	"	¾"	11" " "	" " " "	Floor Beams
20	"	"	17" " "	" " " "	" "
16	"	"	11" " "	" " " "	Hand Rail
4	"	1"	4'6" " "	" " " "	Anchors
4	"	"	9'0" " "	" " " "	"
32	Lag Screws..............	¾"	12" " "		"
120	" "	⅝"	8" " "		Guard Rails
120	Washers	for ⅝"	2" diam.x$\frac{3}{16}$"		
2000	"	" ¾"	3" " x¼"		
1500	"	" ⅞"	3" " x⅜"		
	Nails	60d		300 lbs.	
	"	50d		200 "	
	"	40d		50 "	
	"	20d		50 "	
	"	10d		25 "	
	"	6d		25 "	
	"	4d		10 "	
4	Rods	1" Diam.	21'	225 "	Reinf. Rods
4	"	"	22'	235 "	" "
4	"	"	24'	257 "	" "
4	"	"	26'	278 "	" "
	Concrete	1-2-4 Mix		58.0 cu. yds.	Piers
	Excavation			500 " "	Total
	Painting Outside Only.......			3600 sq. ft.	
	Hauling and Placing Stone from Old Bridge..........			50 cu. yds.	
24	Steel Plates..............	12"x⅜"x4'- 9"		1744 lbs.	
26	" "	12"x⅜"x2'- 3"		896 "	
48	" "	10"x⅜"x1'-11"		1176 "	

STANDARD WOODEN BRIDGES

Montana State Highway Commission, Helena, Mont.

Load 20 Ton Engine Plus 25% Equally Distributed on 8 Joists, ⅔ on Rear Axle

Maximum Length C. to C.	Roadway		
	16′0″	18′0″	20′0″
20′0″	12-4″x18″	12-4″x18″	14-4″x18″
16′0″	12-4″x16″	12-4″x16″	14-4″x16″
12′0″	12-4″x14″	12-4″x14″	14-4″x14″
11′9″	12-3″x16″	12-3″x16″	14-3″x16″
9′0″	12-3″x14″	12-3″x14″	14-3″x14″
8′9″	12-4″x12″	12-4″x12″	14-4″x12″
6′6″	12-3″x12″	12-3″x12″	14-3″x12″

Bill of Lumber

Maximum Spans for Joists Shown

Name	20′0″ E. to E. 19′0″ C. to C.	16′0″ E. to E. 15′0″ C. to C.	12′0″ E. to E. 11′0″ C. to C.	10′0″ E. to E. 9′0″ C. to C.	8′0″ E. to E. 7′0″ C. to C.
			16′0″ Roadway		
Joists......	12-4″x18″x20′	12-4″x16″x16′	12-3″x16″x12′ or 12-4″x14″x12′	12-3″x14″x10′ or 12-4″x12″x10′	12-3″x12″x8′
Floor.......	22-4″x12″x16′	18-4″x12″x16′	14-4″x12″x16′	11-4″x12″x16′	9-4″x12″x16′
Bridging....	9-2″x 4″x16′	9-2″x 4″x16′	5-2″x 4″x16′	5-2″x 4″x16′	
			18′0″ Roadway		
Joists......	12-4″x18″x20′	12-4″x16″x16′	12-3″x16″x12′ or 12-4″x14″x12′	12-3″x14″x10′ or 12-4″x12″x10′	12-3″x12″x8′
Floor.......	22-4″x12″x18′	18-4″x12″x18′	14-4″x12″x18′	11-4″x12″x18′	9-4″x12″x18′
Bridging....	10-2″x 4″x16′	10-2″x 4″x16′	6-2″x 4″x16′	6-2″x 4″x16′	
			20′0″ Roadway		
Joists......	14-4″x18″x20′	14-4″x16″x16′	14-3″x16″x12′ or 14-4″x14″x12′	14-3″x14″x10′ or 14-4″x12″x10′	14-3″x12″x8′
Floor.......	22-4″x12″x20′	18-4″x12″x20′	14-4″x12″x20′	11-4″x12″x20′	9-4″x12″x20′
Bridging....	12-2″x 4″x16′	12-2″x 4″x16′	7-2″x 4″x16′	7-2″x 4″x16′	
			Any Roadway		
Curb.......	3-4″x6″x14′	2-4″x6″x16′	2-4″x6″x12′	2-4″x6″x10′	2-4″x6″x8′
Rail S4S	4-4″x4″x16′	4-4″x4″x16′	3-4″x4″x16′	3-4″x4″x16′	2-4″x4″x16′
	2-2″x4″x20′	2-2″x4″x16′	2-2″x4″x12′	2-2″x4″x10′	2-2″x4″x8′
	2-2″x6″x20′	2-2″x6″x16′	2-2″x6″x12′	2-2″x6″x10′	2-2″x6″x8′
	2-2″x8″x20′	2-2″x8″x16′	2-2″x8″x12′	2-2″x8″x10′	2-2″x8″x8′

Lumber for One Pile Abutment

Name	Pieces	Size	Length	Remarks
Piling.........	6	12″ Butt Diam.	10′0″ in ground	
Cap...........	1	12″x12″	24′0″	
Backing.......	6 or more	3″x12″	12′0″	
"	6 or more	3″x12″	16′0″	

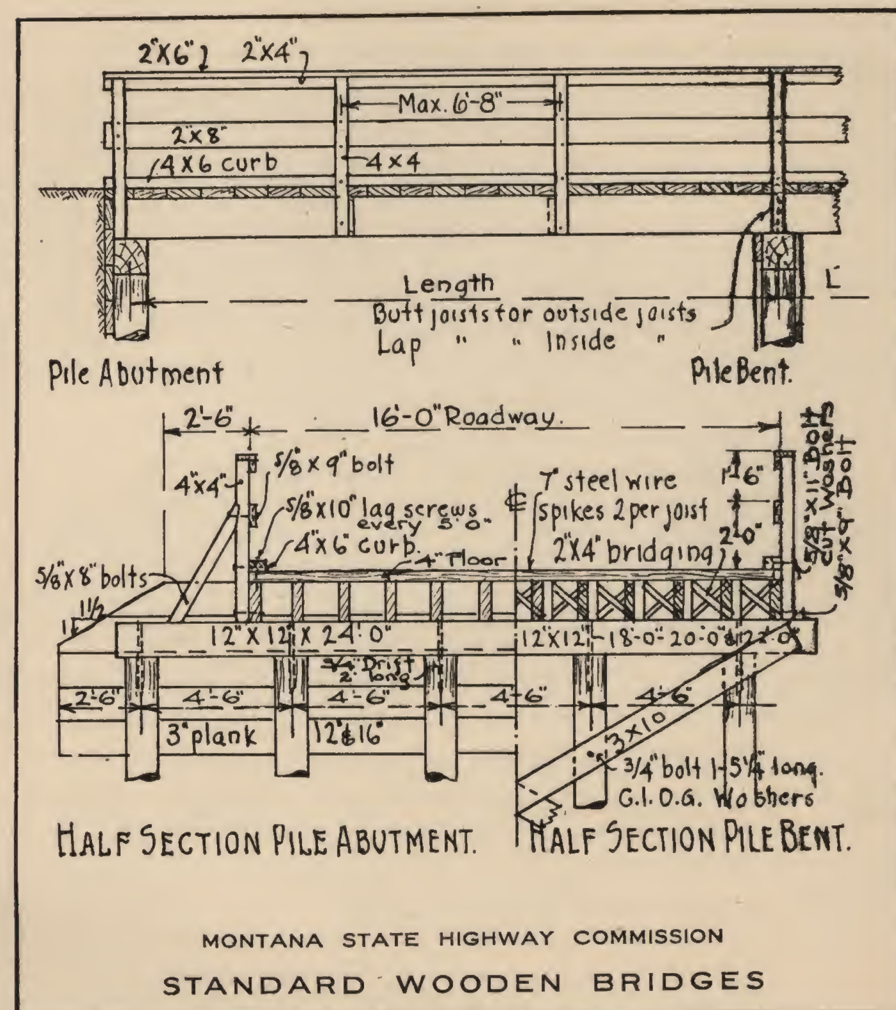


Fig. 27. Details of Small Timber Bridge.

Lumber for One Pile Bent

Name	Roadway	Pieces	Size	Length	Remarks
Piling........	16′ 18′	4	12″ Butt Diam.	10′0″ in ground	
"	20′	5	12″ " "	10′0″ " "	
Cap..........	16′	1	12″x12″	18′0″	
"	18′	1	12″x12″	20′0″	
"	20′	1	12″x12″	22′0″	
Bracing.......	Any	2	3″x10″	18′0″ up.	

All Material to Conform to Montana State Highway Commission Specifications

Bill of Miscellaneous Material

Maximum Spans of Joists

Name	Roadway	20'0" E. to E. 19'0" C. to C.	16'0" E. to E. 15'0" C. to C.	12'0" E. to E. 11'0" C. to C.	10'0" E. to E. 9'0" C. to C.	8'0" E. to E. 7'0" C. to C.
Bridging Nails	Any	6 lbs.-10d	6 lbs.-10d	4 lbs.-10d	4 lbs.-10d	
Rail Nails	"	5 lbs.-40d	4 lbs.-40d	3 lbs.-40d	3 lbs.-40d	2 lbs.-40d
Floor Spikes......	16'	80 lbs.-7"	64 lbs.-7"	48 lbs.-7"	40 lbs.-7"	32 lbs.-7"
" "	18'	80 lbs.-7"	64 lbs.-7"	48 lbs.-7"	40 lbs.-7"	32 lbs.-7"
" "	20'	88 lbs.-7"	70 lbs.-7"	53 lbs.-7"	44 lbs.-7"	35 lbs.-7"
Curb Lag Screws..	Any	10-⅝"x10"	8-⅝"x10"	6-⅝"x10"	6-⅝"x11"	6-⅝"x10"
Rail Bolts........	"	12-⅝"x 9"	12-⅝"x 9"	10-⅝"x 9"	10-⅝"x 9"	8-⅝"x 9"
" "	"	8-⅝"x11"	8-⅝"x11"	6-⅝"x11"	6-⅝"x10"	4-⅝"x11"
" "	"	4-⅝"x8¼"	4-⅝"x8¼"	4-⅝"x8¼"	4-⅝"x8¼"	4-⅝"x8¼"
Pressed Washers..	"	64 for ⅝" Bolts	62 for ⅝" Bolts	50 for ⅝" Bolts	50 for ⅝" Bolts	42 for ⅝" Bolts

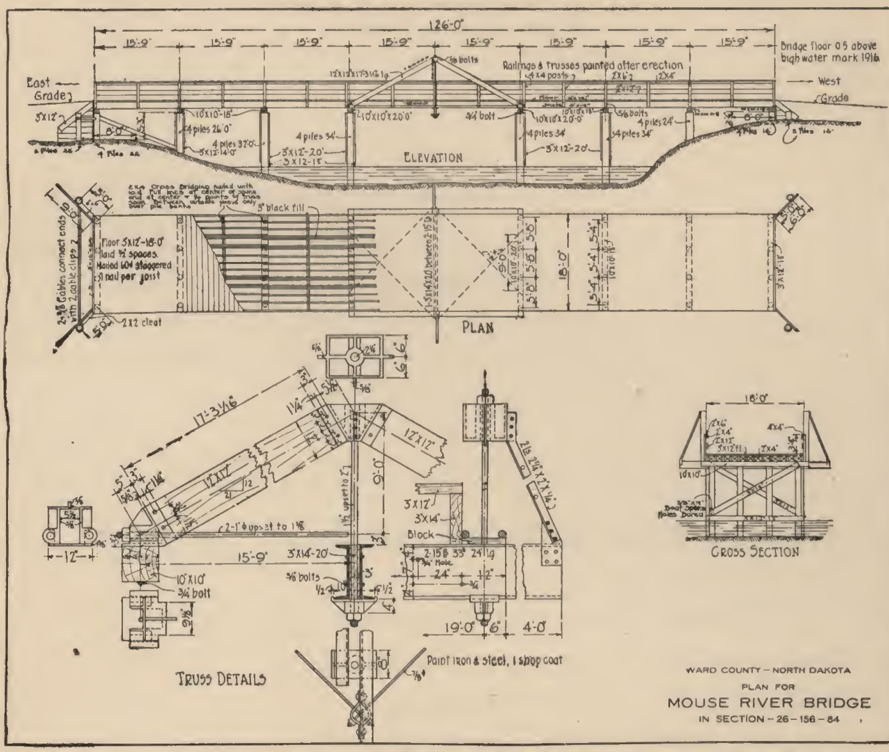
All Nails and Spikes to be Steel Wire

Miscellaneous Material for One Pile Bent

Name	Roadway	Quantity	Size	Length	Kind
Drifts..........	16' or 18'	4	¾" Diam.	2'0"	
Bolts...........	"	4	¾" "	1'5¼"	
Washers........	"	4	for ¾" Bolts		St'd Cast Iron Ogee.
Drifts...........	20'	5	¾" Diam.	2'0"	
Bolts...........	"	5	¾" "	1'5¼"	
Washers........	"	5	for ¾" Bolts		St'd Cast Iron Ogee.

Miscellaneous Material for One Pile Abutment

Name	Roadway	Quantity	Size	Length	Kind
Drifts...........	Any	6	¾" Diam.	2'0"	
Nails for Backing Plk.	"	7½ lbs.	60d		Steel Wire Nails



(Courtesy Ward County Surveyor, Minot, N. D.)

Fig. 28. Timber Bridge of the Trestle Type.

Plan for Mouse River Bridge, Ward County, N. D.

Loading, Dead 25 Pounds per Square Foot, and 100 Pounds per Square Foot or 20-Ton Tractor Live Load

Lumber Required

Pile Braces	8— 3"x12"-20'	Rough	480
" "	2— 3"x12"-14'	"	84
Caps	6—10"x10"-18'	"	900
"	2—10"x10"-20'	"	334
"	1— 3"x14"-20'	"	70
Joists	136— 3"x14"-16'	"	7617
Floor	128— 3"x12"-18'	"	6912
Rail Posts	17— 4"x 4"-10'	SISIE	227
Railing	16— 2"x 6"-16'	"	256
"	16— 2"x 4"-16'	"	171
"	16— 2"x12"-16'	"	512
Truss	4—12"x12"-18'	Rough	864
Backing Braces............	4— 8"x 8"-16'	"	341
Backing	12— 3"x12"-18'	"	648
Wings Braces...............	1— 6"x 6"-10'	"	430
Cross Bridging.............	32— 2"x 4"-14'	SISIE	299
Pile Braces, Horizontal......	4— 3"x12"-18'	Rough	216
Wings	7— 3"x12"-18'	"	374
"	4— 3"x12"-12'	"	144
			20479

Bolts, Spikes, Nails

Boat Spikes	250	⅜″ x 9″
Drift Bolts	32	¾″ x 22″ with heads
Sq. Head Bolts, 2 Washers..	10	⅝″ x 5″
" " " " ..	16	⅝″ x 13″
" " " " ..	4	¾″ x 12″
" " " " ..	70	⅝″ x 7½″
Nails, 60 d	300 lbs.	
" 20 d	60 lbs.	
" 10 d	30 lbs.	

Cost Estimate

Lumber	$490.00
Steel and Cast Iron Bolts	205.00
Nails	14.00
Paint	7.00
Erection	350.00
Miscellaneous	260.00
	$1,326.00

Reference Books on Bridges and Bridge Calculations

Modern Framed Structures.
Johnson, Bryan and Turneaure.

American Civil Engineers' Pocket Book.

Structural Engineers' Handbook.
M. S. Ketchum.

Highway Bridges.
M. S. Ketchum.

Structural Details or Elements of Design in Timber Framing.
H. S. Jacoby.

1915 Manual, American Railway Engineering Association.

A Treatise on Wooden Trestle Bridges.
W. C. Foster.

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J. A. L. Waddell.

Proceedings of American Society for Testing Materials.

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Timber Framing.
Henry D. Dewell.

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